621.8105

A ROWSE MUIR PUBLICATION

CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

T22 X-1
260

OCTOBER 1960 VOLUME 3 NUMBER 28 MONTHLY 3/6

APR 12

DATAflex

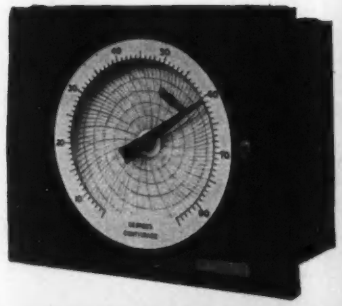
a new advanced system of integrated instrumentation for data handling and industrial process control

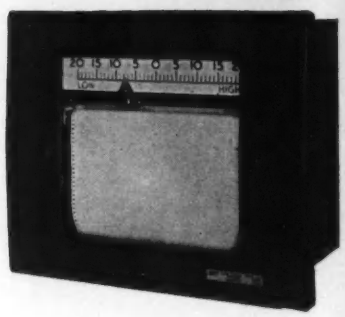
ERICSSON

INSTRUMENT DIVISION

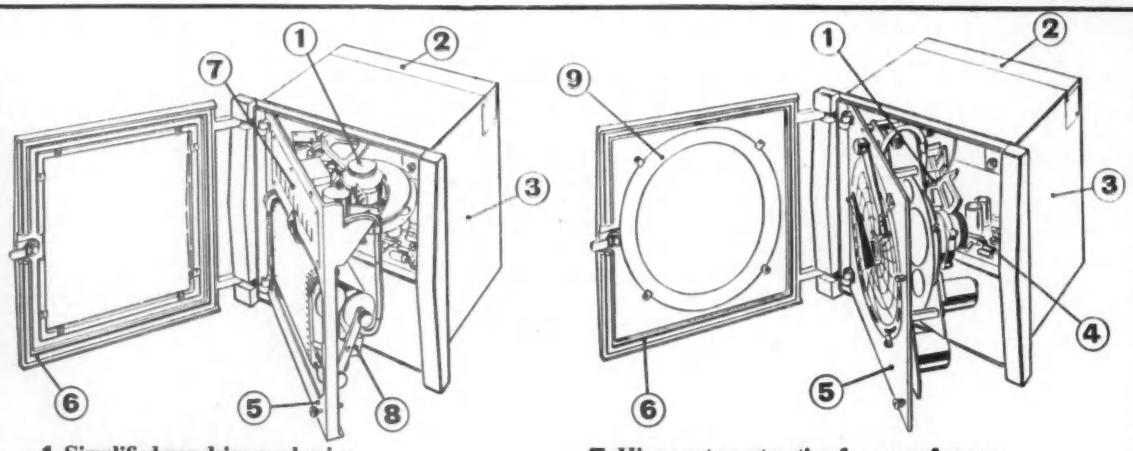
New servo rebalance indicator/recorders offer high performance at low cost

Available in 10″ circular chart and 10″ wide strip chart versions with 1 second full scale traverse and common mechanisms of simple rugged design providing a performance comparable with many more expensive instruments.





Both circular and strip chart versions are available with a wide range of measuring elements of all types–for temperature, pressure, flow, mechanical force, linear displacement. A special feature is the wide range of electrical measurements for which the instruments cater. A three-term control unit and associated electro-pneumatic valve positioner together with a comprehensive range of pneumatically operated valves are also offered in the form of completely integrated schemes.



1 Simplified pen drive mechanism
2 Ease of access for connections
3 Rugged steel case
4 Replaceable control units for required characteristics
5 Hinge-out construction for ease of access
6 Dust-sealed cover
7 Clear easy-to-read scale
8 Hinge forward paper feed mechanism
9 Large diameter indicator scale

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LIMITED

I.D.1. RUGELEY · STAFFORDSHIRE · ENGLAND Metal Industries Group

Manufacturers of the world's widest range of industrial electronic control equipment

A TECHNICAL JOURNAL FOR DESIGNERS AND USERS OF ELECTRICAL, ELECTRONIC, HYDRAULIC, MECHANICAL AND PNEUMATIC CONTROL SYSTEMS AND INSTRUMENTATION

CONTROL

SYSTEMS · INSTRUMENTATION · DATA PROCESSING · ENGINEERING · APPLICATIONS

VOL. 3 NO 28 OCTOBER 1960

MANAGING DIRECTOR A. H. David Rowse, M.A.
EDITORIAL DIRECTOR Caldwell Davidson, M.SC.(ENG.), D.I.C.

EDITORIAL
EDITOR A. Conway, B.SC.(ENG.), A.C.G.I., A.M.I.MECH.E.
DEPUTY EDITORS Lionel A. Stockman, H. G. Bass, M.A.(CANTAB.)
ASSISTANT EDITOR Paul Newnham
EDITORIAL ASSISTANT E. A. Hutcheson
INDUSTRY GUIDE AND DIGEST NUMBER EDITOR Charles E. Steiner

CONSULTANTS
SYSTEMS John H. Westcott, B.SC.(ENG.), PH.D., M.I.E.E.
INSTRUMENTATION Denis Taylor, PH.D., M.I.E.E., F.INST.P.
COMPUTERS & DATA PROCESSING Maurice V. Wilkes, F.R.S.
ENGINEERING & APPLICATIONS Reginald Medlock, B.SC., A.M.I.MECH.E., A.M.I.E.E.

PRODUCTION
MANAGER Gerald Vane, B.A.
ASSISTANTS Donald Ewers, Gerald Withers

CIRCULATION
MANAGER J. W. Rotheroe, B.SC.(ECON.)
ASSISTANT B. W. Stapley

ADVERTISEMENT
DIRECTOR Harry T. Kane
MANAGER Arthur Lawless
SOUTHERN REPRESENTATIVE K. M. Towell
CLASSIFIED John Deamer

MANCHESTER OFFICE
Barry Gibbs
72 Market Street, Manchester 2
tel: Blackfriars 4058
Blackfriars 1919

U.S. OFFICE
Walter J. Masterson, Jr
Box 206, Essex, Conn. *tel:* South 7-1838

HEAD OFFICE
The Rowse Muir Building,
77-79 Charlotte Street,
London, W.1, England
tel: Museum 8252
cables: ROWSEMUIR LONDON

Control is published by Rowse Muir Publications Ltd., and printed by The Haycock Press Ltd., S.E.5. The entire contents are protected by copyright in Great Britain and by the Universal Copyright Convention but matter may be reproduced provided that due acknowledgement is made to *Control*. Subscriptions to publishers Rowse Muir Publications Ltd. Single copies U.K. and overseas 3/6, U.S. and Canada 75c. Subscription U.K. and overseas £2.2.0, U.S. and Canada $8. Three-year subscription U.K. and overseas £5, U.S. and Canada $20.

SPECIAL FEATURES

Controlling the manufacture of laminated plastics
Some home truths for instrument manufacturers spice this article by D. LIDGLEY, D. C. LOWE and D. A. MACKINTOSH of Formica Ltd 88

Farnborough impressions
How M. JAMES, of de Havilland Propellers, saw the control engineering side of this year's S.B.A.C. show 94

Stockholm shows the world
A dispatch from E. H. WERNINCK of Evershed & Vignoles, who was in Stockholm for the fifth International Instruments and Measurements Conference and Exhibition 97

Information theory—the fourth London Symposium
Clear distillate for the control engineer, presented by Dr A. M. ANDREW of the National Physical Laboratory 100

Automatic landing and reliability
Multiplex or multiplicated? Control's *Deputy Editor, L. A. STOCKMAN, discusses the competing approaches* 102

Controlling v.t.o.l. aircraft at transition speeds—2
J. J. FOODY of Short Bros & Harland takes up the question of stability augmentation in jet-lifted aircraft 105

Programming a digital computer for process control
This is the latest in our informal series of articles on process control by computer. Here T. H. GOSSLING of Ferranti sees the possibility of some radically new approaches 109

Automatic control of power reactor systems—*B*
Concluding the second in our series of articles on the control of nuclear power, J. H. BOWEN of the U.K.A.E.A. discusses how system response may best be improved 114

REGULAR FEATURES

Leader: **Switching to the solid state** 83
Viewpoint: **More D.S.I.R.–industry collaboration** *by D. G. Sopwith* 87
Look at America *by J. Lowen Shearer, Robert S. Scher and Karl N. Reid, Jr* 126

Letters to the Editor	84	News round-up	131
Publisher's column	84	Pick-off	136
Ideas applied	119	New for control	138
Control in action	123	Industrial publications	144
Looking Ahead	125	Book reviews	146
People in control	129	Literature received	146
Authors in *Control*	130	Advertisers index	202

LOOKING FOR A JOB? CONTROL *carries the best jobs going in instrument and control engineering.* **SEE PAGE 198 AND ONWARDS**

© 1960

RM ROWSE MUIR PUBLICATIONS LIMITED, LONDON, ENGLAND

TAPER LOCK DESIGN

·260" to 1·020" dia.

PILOT PRACTICALITIES No. 2

A series to acquaint engineers with the very practical advantages of PILOT plug gauges which ***reduce*** *gauging costs.*

The gauging member is held in the handle by means of a taper enabling it to be removed and replaced by a new end when worn undersize. PILOT handles unlike the B.S.I. design are smaller across the corners than the diameter of the gauging member so that the gauge can be used to check a deep hole equal to the length of the "GO" end plus the handle. The handles are heat treated aluminium alloy extruded bar of great strength, and are anodised in five colours. Red, Green, Blue, Amber and Self-colour for identification. The gauge ends are hardened to Rockwell C 65/68 and finished to ·6 micro inches or better, and to within 20 millionths of 'top limit' (the maximum permissible manufacturing size in the BS specification). They are parallel to 20 millionths of an inch or less. In this way the greatest possible life is ensured. Your name is engraved upon the handle!

"PRACTICALLY" PERFECT

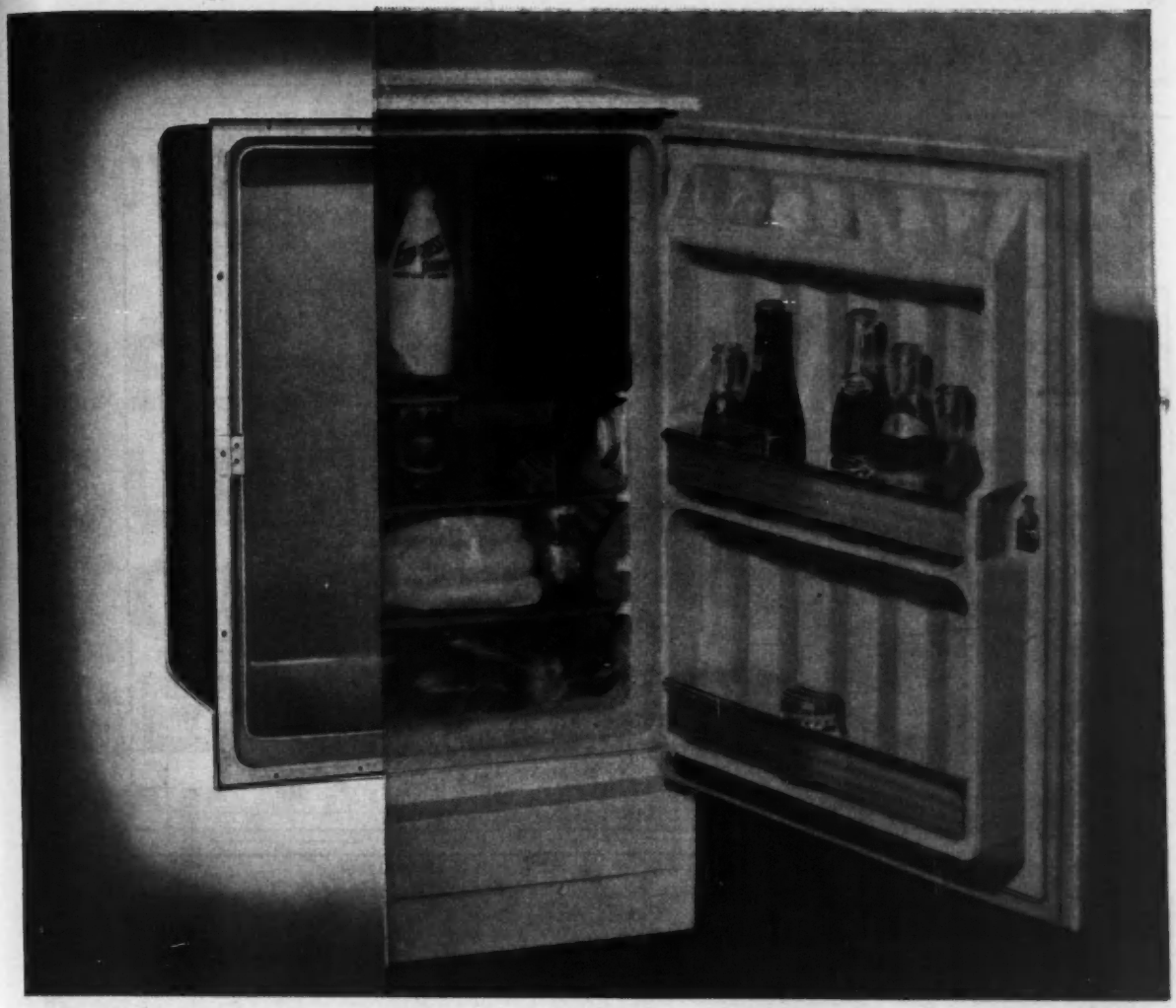
PILOT

PLUG GAUGES

THE PILOT PLUG GAUGE CO LIMITED · SWALLOW ROAD

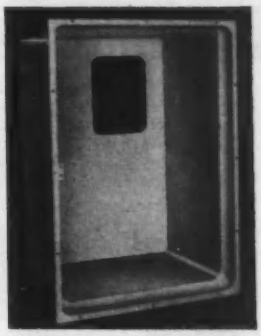
COVENTRY · PHONE: 87341/2

Circle No 3 on reply card for further details



PLASTICS

The liners of modern refrigerators are moulded complete in one operation in high impact polystyrene. The injection moulding machines used in these operations are, it is claimed, the biggest built in the United Kingdom, and employ Vickers-Armstrongs "VSG" variable delivery pumps. Developments in the Plastics Industry continue at an ever increasing tempo, with new methods and machinery continuously being evolved to improve manufacturing standards and to increase the scope of moulding techniques. The use of these pumps in this highly specialised industry is a further example of the many and varied applications of "VSG" equipment which have been serving modern industry for over fifty years.



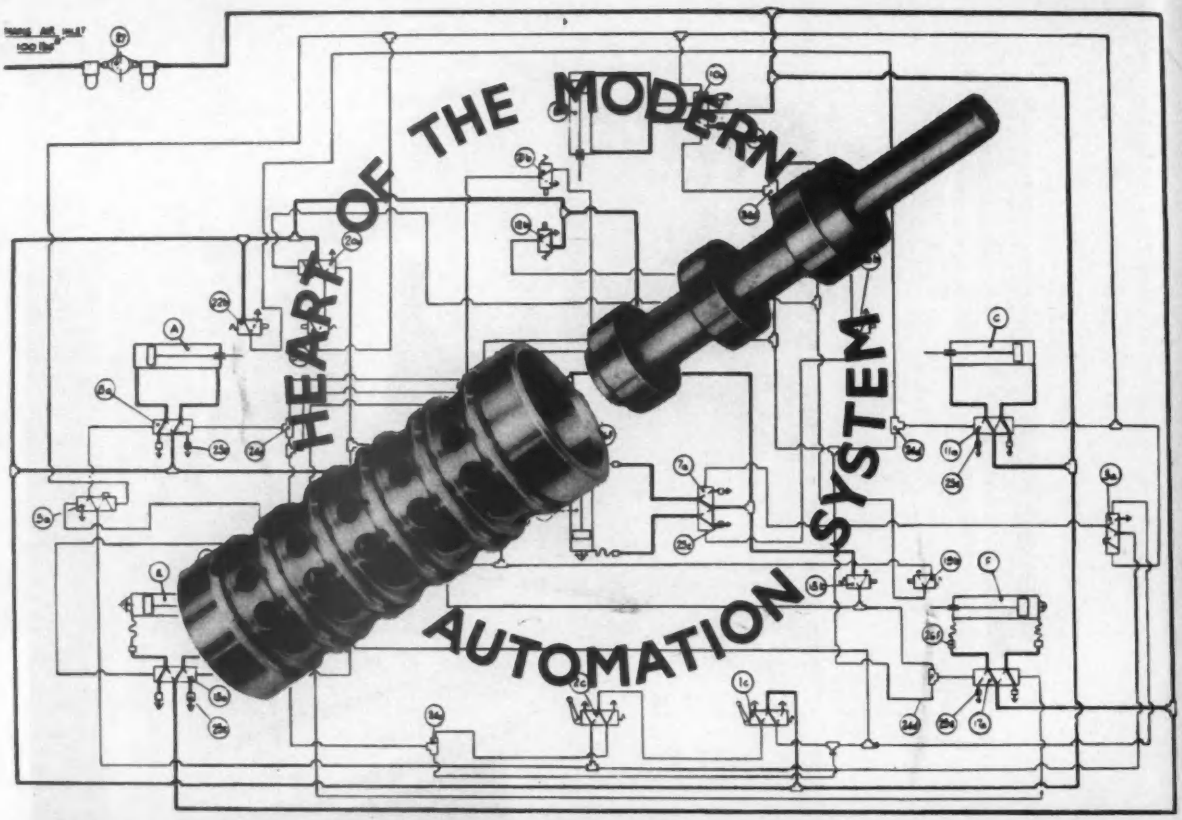
Moulded for Frigidaire by Ekco Plastics on Windsor AP335 machine.

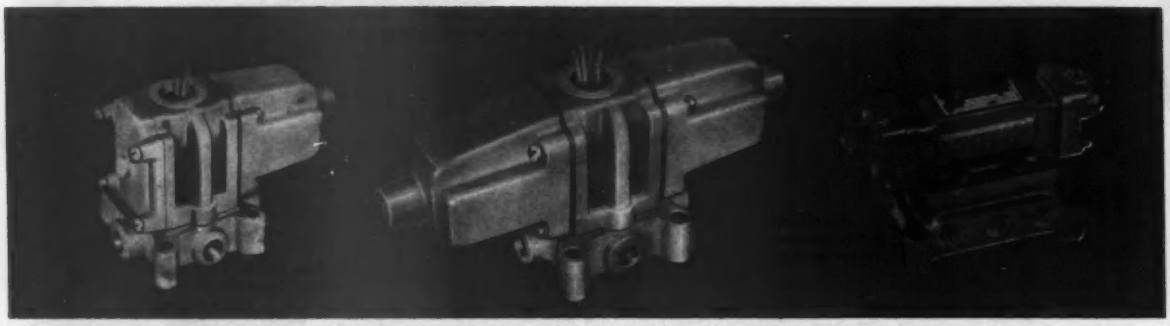
'VSG'

Regd Trade Mark

SERVING MODERN INDUSTRY

VICKERS ARMSTRONGS (ENGINEERS) LTD VICKERS HOUSE BROADWAY LONDON SW1





T.A.L. Numatics instantaneous acting, super high speed valves are the most reliable in the World. Designed with metal to metal seals to give trouble free life they are precision built and super-finished to millionths of an inch. Both spool and sleeve are of heat treated stainless steel.
Full pipe bore through all the valves give long life at high cycle rates and they are suitable for air or vacuum operations. Sub-base and manifold mounted and complete range of accessories, silencers and regulators are available.

Complete pneumatic control circuits engineered and supplied for—

Automatic Machine Tools • Transfer Machines • Welding Machines • All Mechanical Handling Applications • Foundry Machines • Electric Computers Pneumatic Hoists • Clamping and Indexing Fixtures • Vacuum Plants

and any application where air or gas has to be controlled.
We will be pleased to send you full details or get in touch with your nearest Agent.

British Patent Nos. 850465, 850466
Patents in all Industrial Countries

T.A.L. NUMATICS

LIMITED

ENERGY WORKS, LEIGHTON BUZZARD, BEDFORDSHIRE

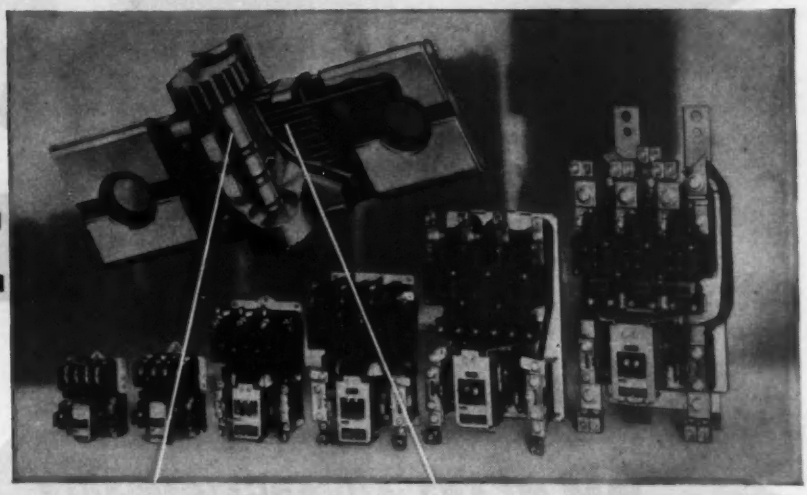
TELEPHONE: LEIGHTON BUZZARD 2581 TELEGRAMS: " CONSULT ", LEIGHTON BUZZARD

Agents for Scotland, Cumberland, Northumberland and Durham, C. & A. STEWART LTD., THORNLIEBANK INDUSTRIAL ESTATE, GLASGOW.
Wales, Monmouthshire and Herefordshire, THE BRITISH FLOTTMANN DRILL CO. LTD., ALLENSBANK WORKS, CARDIFF.
Yorkshire, Nottinghamshire, Derbyshire and Lincolnshire, C. G. ELLISON LIMITED, ALBERT ROAD, MORLEY, Nr. LEEDS. Lancashire, Cheshire and Westmorland, C. G. ELLISON LIMITED, MANCHESTER.

When you buy Motor Starters - -

YOU PAY FOR OVERLOAD PROTECTION

BE SURE YOU GET IT!



Heat-responsive element *(solder pot) provides accurate response to overload, yet prevents nuisance tripping.*

Heat producing element *is an integral part of overload unit. It's permanently joined to solder pot, can't become misaligned.*

Only ONE-PIECE Overload Relays can give 100% Protection.

Only with ONE-PIECE construction can you *know* you've installed the heater correctly. Only with ONE-PIECE construction can you *know* the heater is exactly centred, or properly positioned, so that it performs according to its rating. Only with ONE-PIECE construction can you *know* your starters will not operate without the thermal units properly installed. Only with ONE-PIECE construction can you *know* your motors have full protection.

Only Square D has ONE-PIECE Construction. ONE-PIECE construction eliminates any possibility of heater misalignment. Square D melting alloy thermal overload relays can be installed only one way. They are tamper-proof. They are factory-assembled, are individually calibrated and tested. Repeated tripping will not affect their accuracy.

Insist on square D starters with melting alloy thermal overload relays

LET US PROVE IT!

Let your Square D Field Engineer show you 1 how one-piece construction is accomplished and how easy it is to mismatch separate heaters and solder pots — 2 a tripping time tester to compare various types of melting alloy units and to prove that tripping time won't change after repeated operation.

LEADERS IN CONTROL GEAR FOR OVER 50 YEARS.

To have the best Specify Square D

SQUARE D LIMITED

CHENEY MANOR SWINDON WILTSHIRE

Square D products are stocked by leading electrical wholesalers throughout Great Britain.

FIELD OFFICES — LONDON · BIRMINGHAM · MANCHESTER · GLASGOW · NEWCASTLE · BRISTOL · LEEDS

HA33

UNBRAKO AD

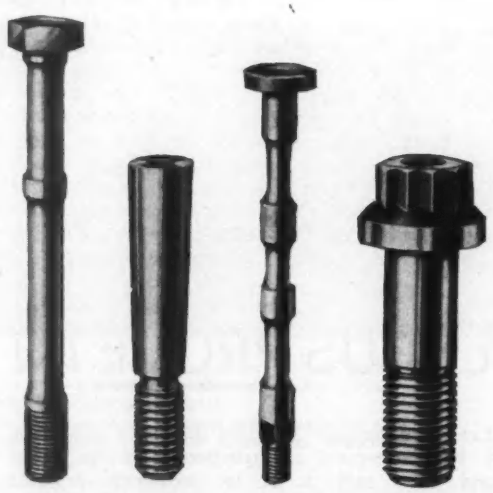
AD ***MEANS ADVANCED DESIGN***

A NEW DIVISION WITHIN THE UNBRAKO ORGANISATION DEVOTED TO NEW THINKING IN NEW MATERIALS

Something new in the fastener world—a division making the future its special concern.

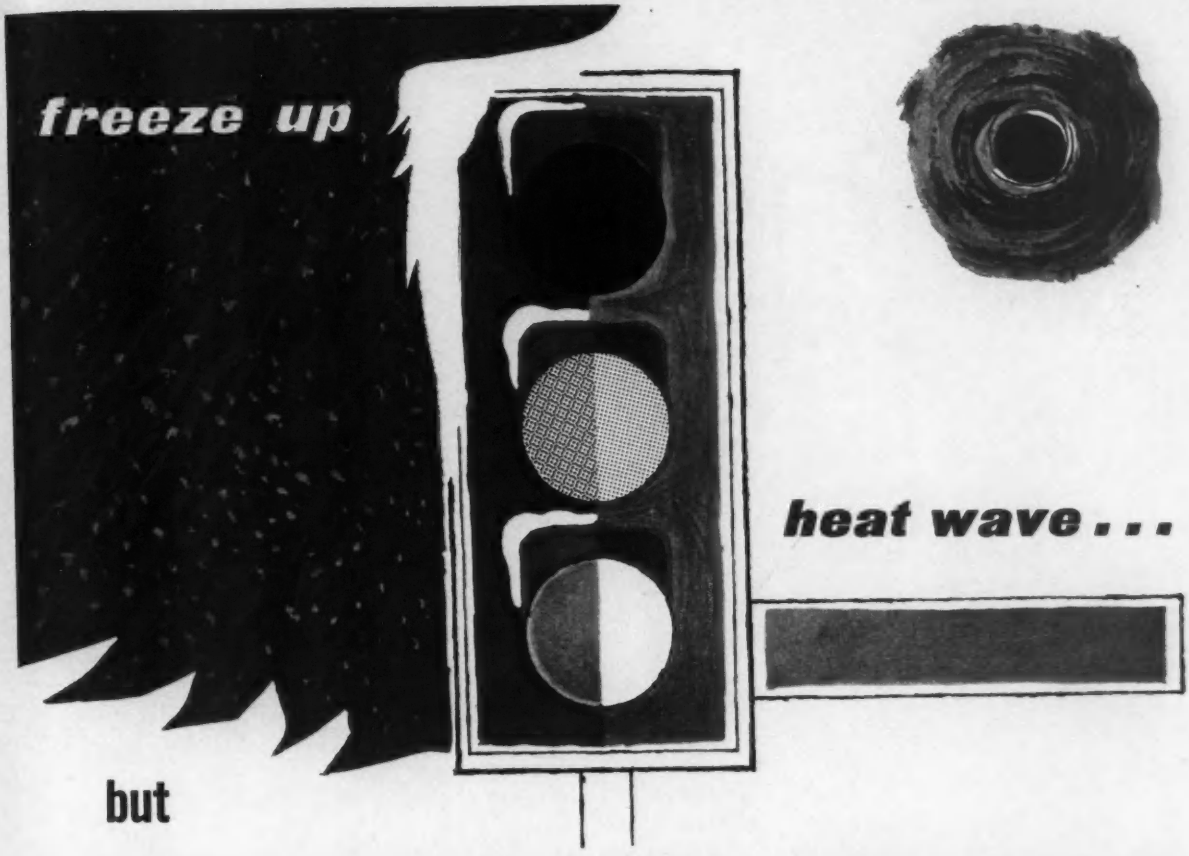
Using the latest high performance alloys such as 'Nimonic' and Titanium, UNBRAKO AD produce revolutionary fasteners that will be accepted as standard in years to come.

Today, the men behind the achievements of modern industry naturally choose Unbrako fasteners. The inception of the Advanced Design Division is a logical step into their future.



UNBRAKO-AD

UNBRAKO SOCKET SCREW COMPANY LIMITED, COVENTRY. TEL : 89471



HOLTZER-CABOT MOTORS

provide unfailing *power for control*

Even Holtzer-Cabot Motors haven't *solved* America's traffic problem. But they are helping to minimize it by providing traffic-light sequence control that can be relied on under every kind of weather. In many other countries, these efficient synchronous and induction motors have proved themselves for varied applications, in ambient temperatures ranging from 0°C to 70°C +. Over a million have been installed in specialized servo control and measuring equipments and many are on duty twenty-four hours a day, seven days a week.

● PUMPS ● SEQUENCE-TIMING EQUIPMENT ● MOTORISED VALVES ● FANS
● TENSIONING AND WINDING EQUIPMENT ● STRIP CHART RECORDERS

Ask for detailed information on these rugged precision-built motors — available for speeds from 1500 rpm down to ¼ rpm, voltages to 250 v, special windings if required.

ELLIOTT

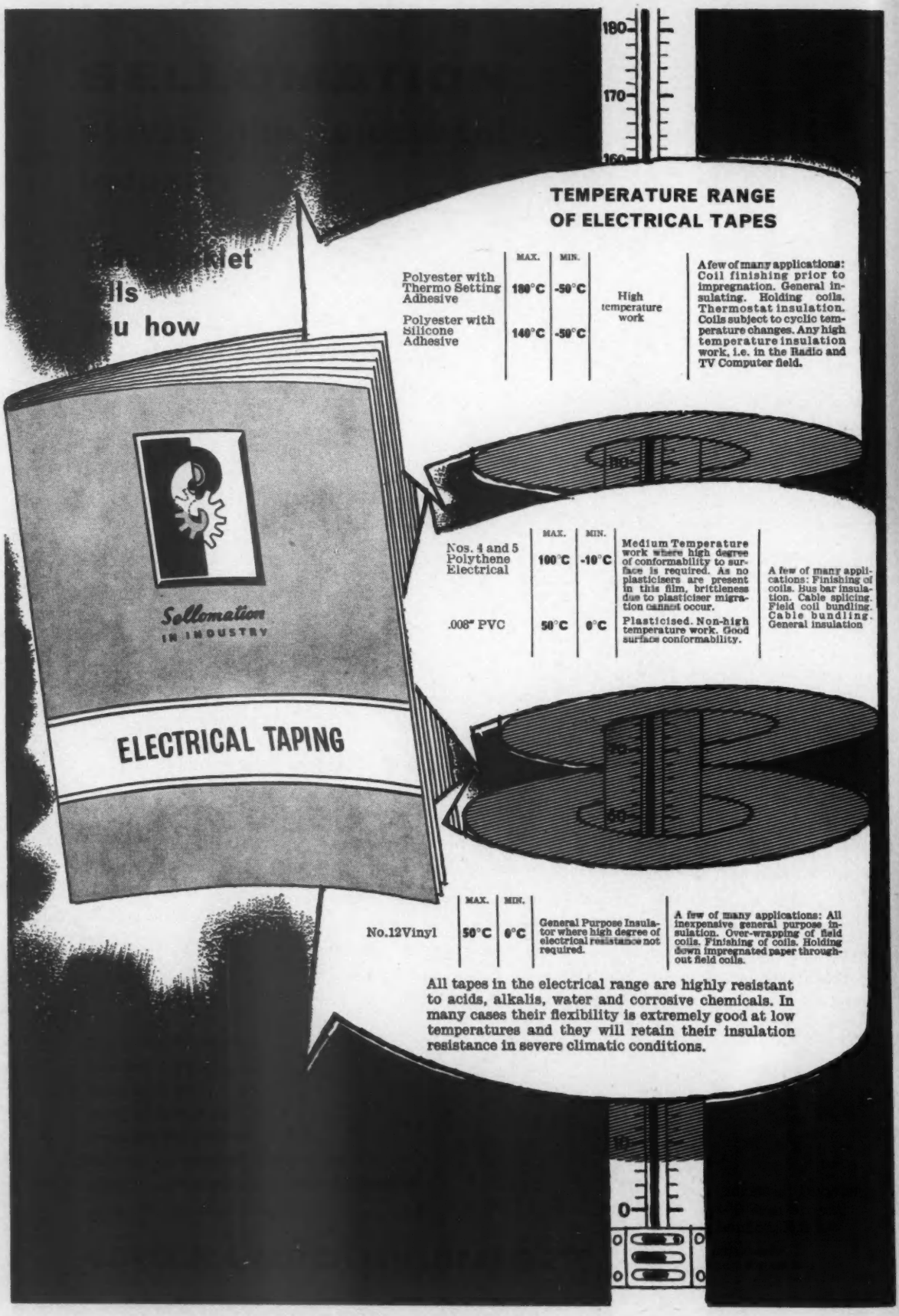
Manufactured under licence by
SERVO COMPONENTS DIVISION
ELLIOTT BROTHERS (LONDON) LTD
CENTURY WORKS, LEWISHAM SE13

A MEMBER OF THE ELLIOTT-AUTOMATION GROUP

REMOTE INDICA

Evershed supervisory control units enable up to 40 plant functions to be remotely controlled over two wires with indications and alarms operating in the opposite direction over the same two wires. The system is self-monitoring and constantly checks its own synchronization. It also provides for telephone communication again over the same two wires. The illustrations show panels in use at Colchester where remote and local water reservoir levels are indicated and recorded and distant control valves and borehole pumps are operated automatically. This telemetering system makes Colchester Corporation's Water Works one of the most up-to-date in Great Britain.

EVERSHED



TEMPERATURE RANGE OF ELECTRICAL TAPES

	MAX.	MIN.		
Polyester with Thermo Setting Adhesive	180°C	-50°C	High temperature work	A few of many applications: Coil finishing prior to impregnation. General insulating. Holding coils. Thermostat insulation. Coils subject to cyclic temperature changes. Any high temperature insulation work, i.e. in the Radio and TV Computer field.
Polyester with Silicone Adhesive	140°C	-50°C		
Nos. 4 and 5 Polythene Electrical	100°C	-10°C	Medium Temperature work where high degree of conformability to surface is required. As no plasticisers are present in this film, brittleness due to plasticiser migration cannot occur.	A few of many applications: Finishing of coils. Bus bar insulation. Cable splicing. Field coil bundling. Cable bundling. General insulation
.008" PVC	50°C	0°C	Plasticised. Non-high temperature work. Good surface conformability.	
No.12Vinyl	50°C	0°C	General Purpose Insulator where high degree of electrical resistance not required.	A few of many applications: All inexpensive general purpose insulation. Over-wrapping of field coils. Finishing of coils. Holding down impregnated paper throughout field coils.

All tapes in the electrical range are highly resistant to acids, alkalis, water and corrosive chemicals. In many cases their flexibility is extremely good at low temperatures and they will retain their insulation resistance in severe climatic conditions.

REDIFFUSION

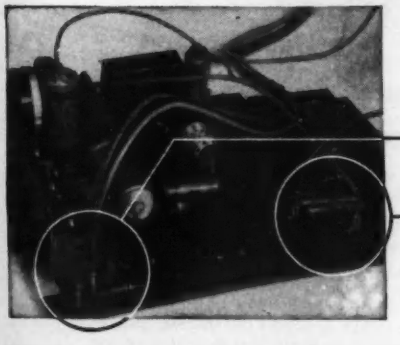
uses *AMP

solderless wiring devices

Auto/Machine applying AMPin and Miniature Faston terminals.

Close-up showing application of AMPin to wire.

* Miniature Faston



AMPin for permanent connection of leads to Time Base circuit.

Miniature Faston for quick connect disconnect of leads to board.

. . . to the end

▲ SPEEDY APPLICATION ▲ LOWER APPLIED COSTS ▲ UNIFORM HIGH QUALITY ▲ HIGH ELECTRICAL AND MECH

WRITE NOW ABOUT THE **CREATIVE** APPROACH TO BETTER WIRING

AIRCRAFT-MARINE PRODUCTS (GT. BRITAIN) LTD.

Head Office: Dept. 23, AMPLO HOUSE, 87/89 SAFFRON HILL, LONDON, E.C.1.
Tel: CHAncery 2902 (7 lines) Telex. 23513 Cables: AMPLO LONDON TELEX.
Works: Scottish Industrial Estate, Port Glasgow, Scotland.

AMP ★ TRADE MARK

*Trade Mark of AMP Incorporated. U.S.A.

SOUTH AFRICA: DISTRIBUTOR: E. S. HOWAT & SONS (PTY) LTD. 51-57, MILNE STREET, P.O. BOX 437, DURBAN, NATAL, SOUTH AFRICA
AUSTRALIA: MANUFACTURING COMPANY: AIRCRAFT-MARINE PRODUCTS: (AUSTRALIA) PTY. LTD. BOX 78, P.O. AUBURN, N.S.W. AUSTRALIA
DISTRIBUTOR: GREENDALE ENGINEERING AND CABLES PTY. LTD., 43-51 NELSON STREET, ANNANDALE, N.S.W. AUSTRALIA
ASSOCIATED COMPANIES IN: U.S.A. CANADA, HOLLAND, FRANCE, GERMANY, ITALY, JAPAN, PUERTO RICO AND MEXICO

AP134

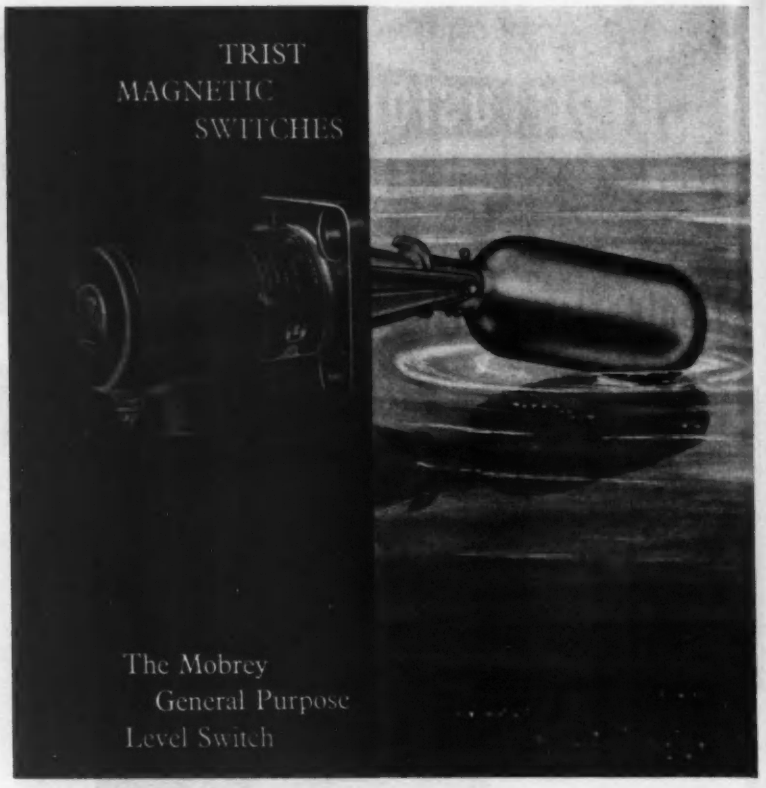
RONALD TRIST

& CO. LTD.

(a company of the Bell's Asbestos & Engineering Group)

Bath Road, Slough, Bucks

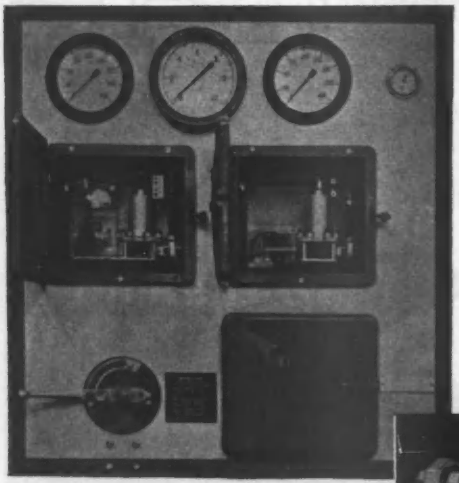
Phone: Slough 25041. Telegrams: Revalar, Slough



For indicating or controlling liquid level in tanks and similar vessels.
Employed as a high- or low-level alarm its contacts are wired in conjunction with an indicating lamp or some audible warning device. Used for controlling an electrically driven pump supplying liquid to or extracting liquid from a vessel, its contacts are wired in conjunction with the contactor coil in the pump motor starter. There are over 100 different types of switch available for use in almost any liquid.

Please ask for Brochure C/M160

Automatic Control



A section of the remote control, push-button unit, showing some of the timers, relays and contactors.

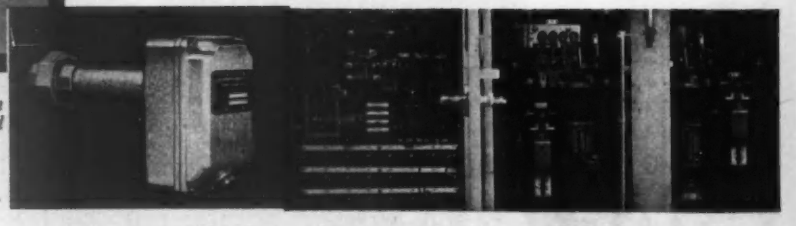
for Water Tube boilers

Shell boilers · Marine boilers

Industrial Processes

Heat exchangers, thermal and nuclear

The John Thompson La Mont auxiliary boilers as supplied to the Alfred Holt shipping line are fitted with automatic controls by John Thompson Instrument Co. Pressure controls, high pressure cut-outs, flame failure and air flow controls are linked with multiple safety features to give a compact reliable system.



A John Thompson Flame Failure unit fitted to the burner.

The control panel housing the pressure controls manual/automatic switch lever, pressure, temperature and draught gauges.

JOHN THOMPSON INSTRUMENT CO LTD · WOLVERHAMPTON

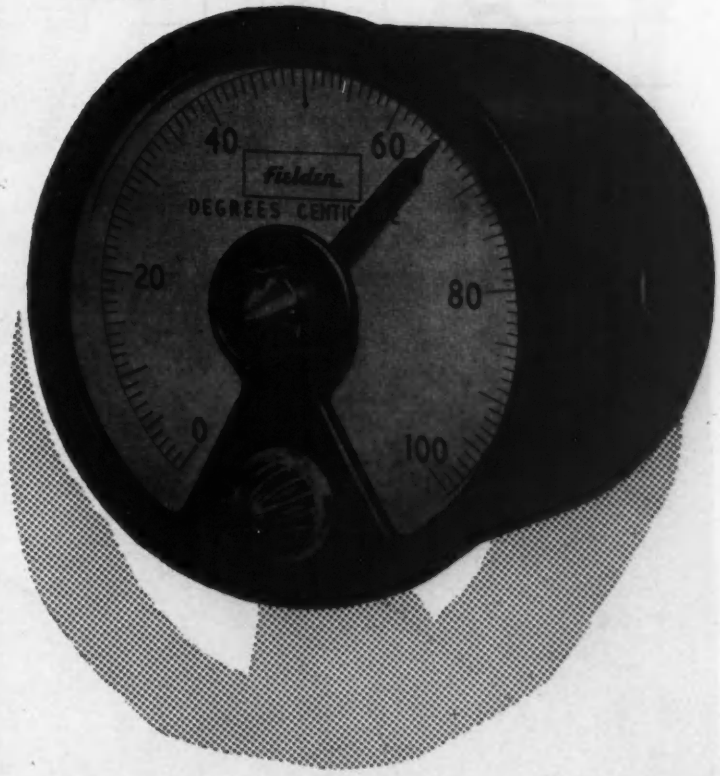
MF 5a

Fielden Controllers mounted on the sloping panel of a Brown Davidson Moulding Machine

NEW BIKINI TRANSISTORISED TEMPERATURE CONTROL to within 0.5° C

The first of Fielden's new BIKINI range of transistorised instruments. Result of three years intensive research, development and evaluation. Small in size and small in price. In brief, it's appealing.

Low Cost—Send for details.
Transistorised—Exceptional reliability. No warming up period. 12V Battery or mains supply.
Intrinsic Safety—Low voltage, low current operation—Intrinsic safety certificate pending.
Very Robust—completely sealed unit requires no attention. No pivots, galvos or other delicate moving parts.
Easily fitted—simple clamp mounting with robust terminals for electrical connections. Can be mounted at any angle, for example on a sloping control panel.
Remote control—Instrument can be up to 300 ft away from the measuring point using simple copper wiring. Measuring element is of platinum resistance type, housed in a robust ¼" diameter stainless steel sheath.
Heavy Duty Contacts—Change over electrical contacts rated at 5 amps A. C. with quick make and break action. Pneumatic control available if required.
Accurate calibration—Accurately calibrated scale 9" long marked in °C or °F. Easily set to required control temperature.
High stability—Control point will not vary over many years service. Unaffected by ambient temperature changes or by wide variations in supply voltage.
Wide Temperature range—will control at any temperature between —200° C and +500° C with a differential of 0.5° C. Range spans as low as 50° C.
Modern and Compact—Circular meter type case. Occupies panel space of only 4½" diameter. Bold pointer shows control temperature. Red lamp, visible from sides and front, indicates control action.
Immediate delivery—Instruments ranged 0-120° C, 0-200° C, 0-300° C and 0-500° C available from stock in Manchester, London, Walsall, Stockton and Edinburgh. Other standard ranges in stock at Manchester. Telephone your urgent requirements to Wythenshaw 3251 Trafalgar 3154, Walsall 28343, Stockton 68617 or Craig Lockhart 5235.



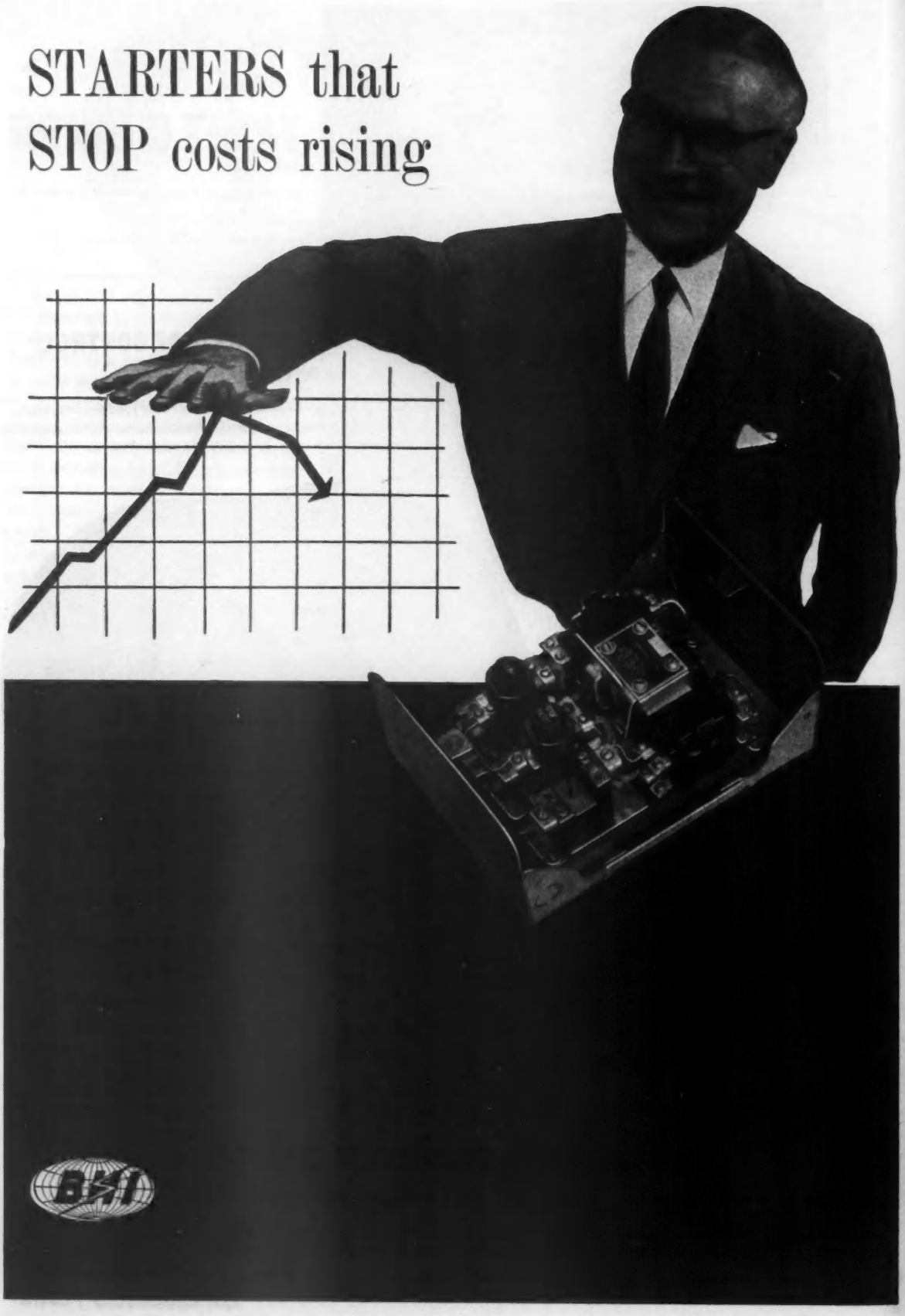
Write now for full specification sheet BIK. 1/C with price list.

Fielden

FIELDEN ELECTRONICS LTD · WYTHENSHAWE · MANCHESTER Phone: Wythenshawe 3251 (4 lines) Grams: Humidity Manchester
ALSO AUSTRALIA, ITALY & CANADA *Branch Offices:* LONDON, WALSALL, STOCKTON-ON-TEES, EDINBURGH & DUBLIN
Agents throughout the world

Indicating Recording Control

STARTERS that STOP costs rising



GEC

Special Works Memo

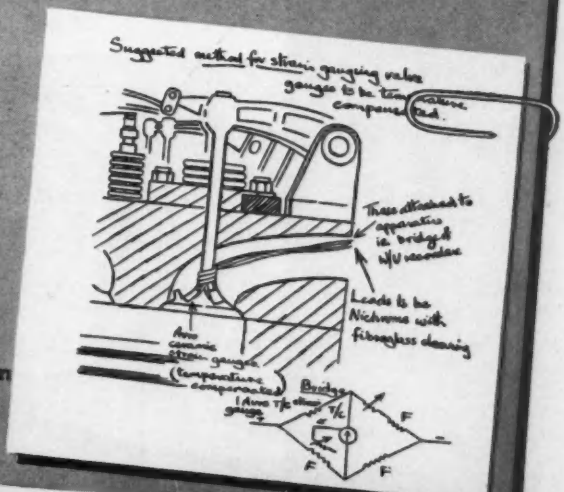
TO Production Engineering and Process Control Depts.

FROM Chief Engineer, Special Projects Division.

Tests have been carried out on two new Armstrong Whitworth Equipment products. Results have been excellent and these items might well be the answer to several of our problems. Preliminary details are:-

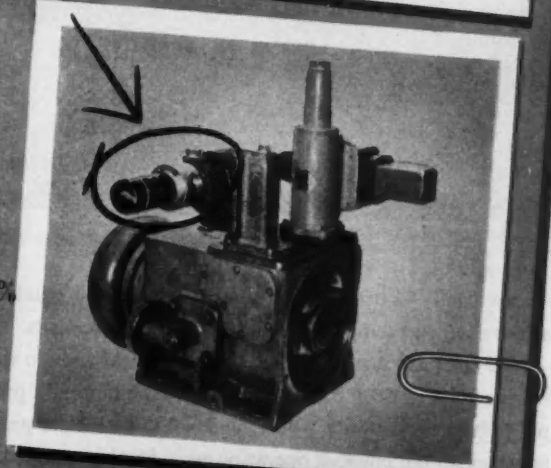
(1) Avro High Temperature Strain Gauges

Strain or minute structural variation measurable accurately at temperatures up to 1,000°C. Transverse resistance cross sensitivity negligible due to rectangular grid section design and stray thermo-electric effects nil. Ceramic cement impregnated non-removable fibrecloth backing bends around small radii. Fixing is by proven adhesives. Illustration shows typical hot point use for gauges. Note that temperature compensating thermo couples may be supplied built into each gauge!



(2) Limited Angle Tacho-Generator

Operates on a 30° angle about a mid position.
Size 1" rotor (2" nominal dia. case 3.75" long). There is also a 3" diameter rotor generator for special order.
Sensitivity 6 volts/radian/sec. ±15%
Load 27 kil-ohms
Frequency response 3 db down at 37 cycles/sec.
Winding resistance 1,680 ohms ±5%
Operating torque 500 gm. cm.
Direct lever drive eliminates gear back lash discrepancies.
Illustration shows use for velocity feed-back measurement on swash-plate pump driving large machine tool.



ARMSTRONG WHITWORTH EQUIPMENT, Hucclecote, Gloucester. Telephone: Gloucester 66781
SIR W. G. ARMSTRONG WHITWORTH AIRCRAFT LTD., MEMBER OF HAWKER SIDDELEY AVIATION

-55°C to +155°C

Plessey mark 5 connectors

This new range of aluminium Mark 5 connectors embodies the main features of the well-established Plessey Mark 4 connector plus additional characteristics for safe operation between −55°C and +155°C!

Designed specifically to provide thoroughly efficient and reliable service at the extended temperatures of modern requirements, the Mark 5 range has passed successfully Type Approval tests to the conditions specified in DEF 5321 (July 1958), maintaining a pressure sealing of 20 lb. p.s.i. between −40°C and +155°C. Where pressure sealing is not essential, efficient operation to −55°C is attained. This standard of performance has resulted in the Mark 5 Connector being adopted by the Ministry of Aviation as the Pattern 104 connector.

Wiring and Connectors Division

THE PLESSEY COMPANY LIMITED · Cheney Manor · Swindon · Wilts · Swindon 6251

Overseas Sales Organisation: PLESSEY INTERNATIONAL LIMITED · ILFORD · ESSEX · ILFORD 3040

CWI9a

AEI INSTRUMENTATION INFORMATION SERVICE

THE ONLY HELIUM-FILLED

TEMPERATURE TRANSMITTER

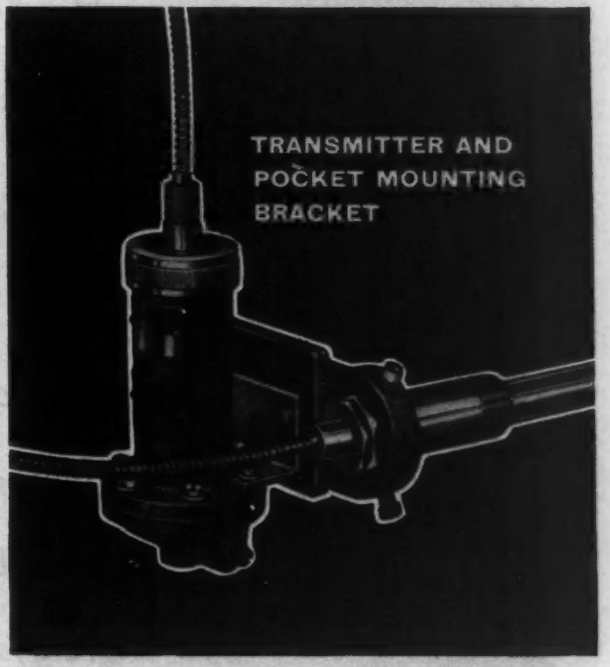
LEAK TESTED BY MASS SPECTROMETER

After filling and sealing, the entire system of every AEI pneumatic temperature transmitter is tested by an AEI mass spectrometer capable of detecting leaks as small as one part in 10^9. An exceptionally stable and drift free instrument is thereby ensured. The thermal system has a high speed of response yet the helium fill is chemically inert so that the instrument is ideal for chemical, oil and food applications. Absence of moving parts in the transmitter—which works on the null-balance principle—ensures negligible maintenance.

Temperature spans:
min. 50°F. max. 900°F.

Ambient temperature limits:
−60°F. to + 200°F.

Copper or stainless steel elements:
capillary armoured in stainless steel.



Mail this coupon for full details

Please send full technical specification of the model 33H temperature transmitter

NAME _____

POSITION _____

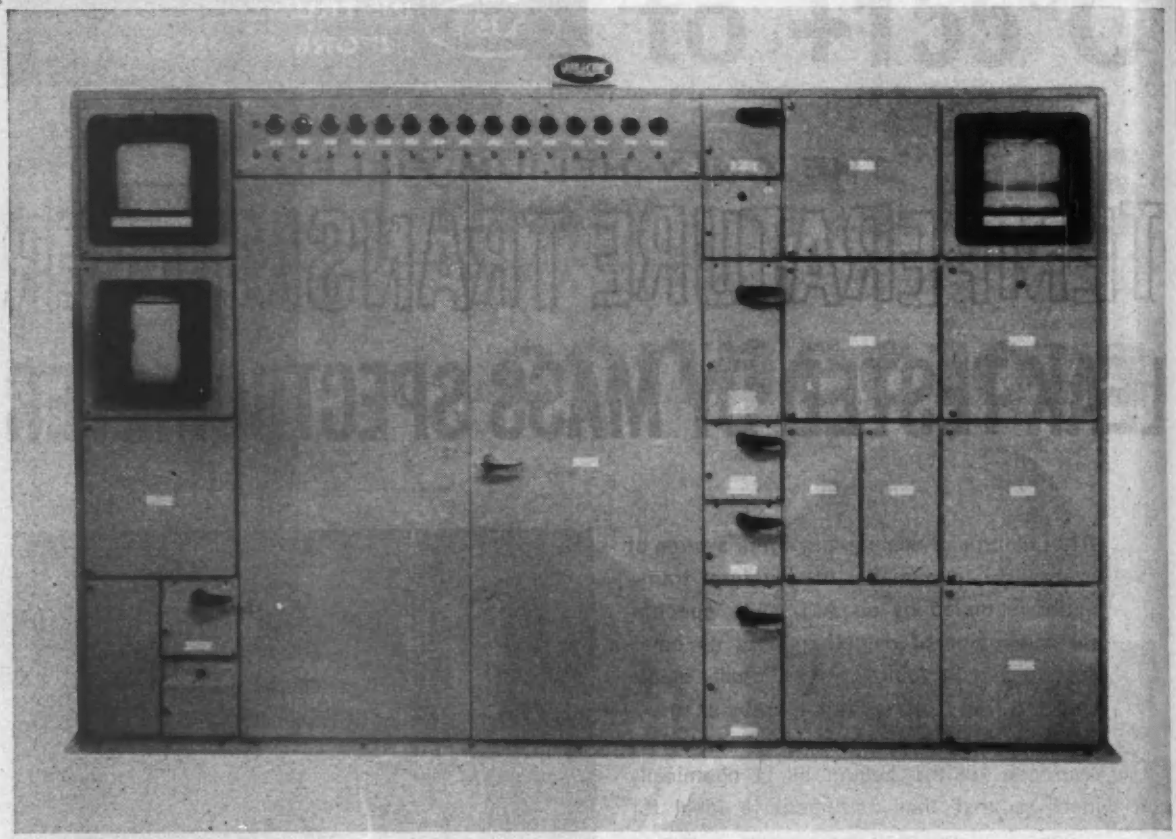
ADDRESS _____

_____

AEI

Instrumentation Division
P.O. Box 1 · Harlow · Essex · Tel: Harlow 25271
Associated Electrical Industries Limited

SC/104



Cubicle Pattern Switchboards incorporating fused switches, distribution boards, contactors and relays, such as illustration, save space and money.

Our full range, includes L.T. Air Circuit Breakers, Rising Main and Overhead Busbars, Distribution Fuseboards, Skirting Ducting, Underfloor Ducting and Motor Starter Cubicles.

VARILECTRIC LTD., 10 MELON ROAD, PECKHAM, LONDON S.E.15

Telephone: (Works Office) RODney 6895/6/7 *Telegrams and Cables:* VARITRIC-S.E.15-LONDON

JONES-TATE

PRESENT

The New **100 S.D. SERIES**

Electrical Valve ACTUATORS

NO OTHER ACTUATOR *provides these* **STANDARD FEATURES:–**

- **WEATHERPROOF**
- **NO FIRE HAZARD**
  Unit does not run in oil bath
- **MINIMUM OVERHANG**
- **NO RESTRICTION ON INSTALLATION ANGLE**
- **SEATING THRUST** controlled by sensitive **TORQUE SWITCH**
- **AUTOMATIC TRANSFER**
  Power drive to Handwheel and vice versa
- **REPETITIVE HAMMERBLOW**
- **HIGH EFFICIENCY SPUR GEARING**

ANY VALVE ANY SIZE ANY ANGLE

Rising or non-rising spindles · Stem Diameters up to 4½"
Valve spindle torques from 60-3500 lb./ft. at 24 r.p.m.
Thrusts from 12,000 to 150,000 lbs. · Air or natural gas operation
Also available flameproof-weatherproof versions

Years ahead for years to come!—Send for full technical details

JONES TATE AND COMPANY LTD. (DIVISION OF DEWRANCE)

VICTORY WORKS, EAST PARADE, BRADFORD Tel. BRADFORD 28348-9 Grams. VALVE, BRADFORD

LONDON OFFICE: 165 Great Dover Street, London, S.E.1 Tel. HOP 3100

Photograph by courtesy of de Havilland Aircraft Company

...Wise Engineers

increase reliability and
reduce maintenance frequency with

Rocol Molybdenised lubricants

Plating tough, wear-resistant molybdenum-disulphide on to all bearing surfaces, Rocol Molybdenised Lubricants stay in action when other lubricants fail, easily coping with extremes of temperature and pressure. Available as a paste, grease, or oil in a wide variety of convenient packs including handy tubes and aerosol sprays.

Find out more about Rocol Molybdenised Lubricants. Write today for technical details — or advice on your particular problem.

* Rocol Molybdenised Lubricants are used and solely recommended on the following applications for all series of Comet 4 aircraft: Emergency changeover mechanism, Elevator universal joints, Screw jack of elevator gear change unit, Elevator and rudder trim screw jack, Elevator trim mechanism, Rudder trim gearbox, de-icing mechanism.

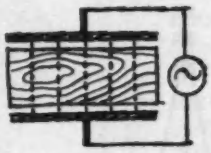
... USE *Rocol* MOLYBDENISED LUBRICANTS

ROCOL LIMITED
General Buildings, Aldwych, London, W.C.2. Tel: HOLborn 1985
Rocol House, Swillington, Nr. Leeds. Tel: Garforth 2261

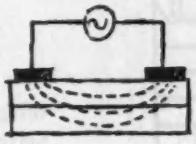
Electrical Aids in Industry — *Data Sheet* **No. 10**

Dielectric Heating - 1

When an electrically non-conducting material is placed between two metal plates, called electrodes, connected to an A.C. supply, the alternating electrostatic field between the electrodes considerably speeds up the molecular movements in the material (termed a 'dielectric') as a result of which the temperature of the material under treatment rises. A similar effect is produced where the two electrodes are positioned on the same side of the dielectric; in this case the electrostatic field between them is generally known as a 'stray' or 'fringe' field.



For industrial application, the applied voltage of up to about 15,000 volts supplied by an electronic generator alternates at frequencies of some millions of cycles per second.



The amount of heat generated in the dielectric is determined by the frequency, the square of the applied voltage, the dimensions of the object and a physical property of the material termed "loss factor" and is represented by the equation:—

$$\text{Power} = 1.41\ E^2\ f.\ F\ \frac{A}{t} \times 10^{-15} \text{ kilowatts.}$$

Where E = applied voltage,
f = frequency (cycles/sec.), F = loss factor.

A = area of the dielectric in square inches.

t = thickness of the dielectric in inches.

F, the loss factor, is itself equal to the expression K Cos Ø in which:
K = the dielectric constant, a measure of the property of the material to retain energy arising from disturbance of its molecular structure.

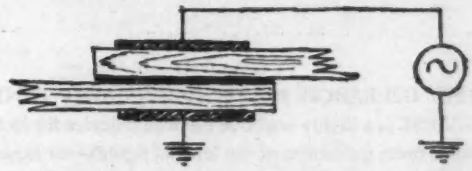
Cos Ø = the dielectric power factor of the load, that is the ratio of the power (in watts) to the product (in volt-amperes) of the voltage and current. This is a characteristic property of the material.

Therefore, "loss factor" is a property of the material and a measure of the ease with which it can be heated by this method. Like other physical properties, it varies considerably for different substances. The equation shows that the heat generated in a dielectric is proportional to its loss factor, but the rate of rise of temperature will also depend upon its specific heat and density. The following table gives approximate values of the dielectric constant, power factor and loss factor of a few typical dielectric materials for frequencies around a million cycles a second.

MATERIAL	DIELECTRIC CONSTANT	POWER FACTOR	LOSS FACTOR
Natural Rubber	2.9	0.02	0.058
Oak, dry	3.3	0.04	0.132
P.V.C.	5.3	0.06	0.318
Urea formaldehyde	7.0	0.03	0.21
'Bakelite' resin	6.0	0.03	0.18
Nylon	3.7	0.05	0.185
Water, pure	80.0	0.03	2.40
Water, tap	80.0	0.05/0.5	4/40

The high loss factor of water means that materials which are difficult to heat when completely dry will often heat efficiently when moisture is present. The voltage must be increased towards the end of the process in some cases to remove the final moisture traces, the reduction in loss factor as the material dries out providing a safeguard against overheating.

Dielectric heating of a homogeneous material is a straightforward application, heat being generated uniformly throughout. If the workpiece is made up of a number of materials, each material will heat up uniformly but each at a rate depending upon its loss factor, thermal properties and density. The degree of temperature uniformity throughout the workpiece will then depend upon the extent to which thermal conductivity can equalise different rates of heating.



Such different rates of heating can be turned to good account in certain applications. For example, in wood glue setting, the glue lines heat up much more rapidly than the wood pieces being joined and the glue sets before the wood heats up substantially, wood having a lower loss factor than glue. Dielectric heating does not depend upon any external heat source to transfer heat by conduction, convection or radiation to the surface of the charge and from thence to the interior by conduction.

Instead, heat is generated within every particle of a body placed in the dielectric field and, depending upon the uniformity of such a body, an even and extremely fast temperature rise can be achieved.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available—"Induction and Dielectric Heating" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

6776

THIS IS THE GILBARCO GAUGE

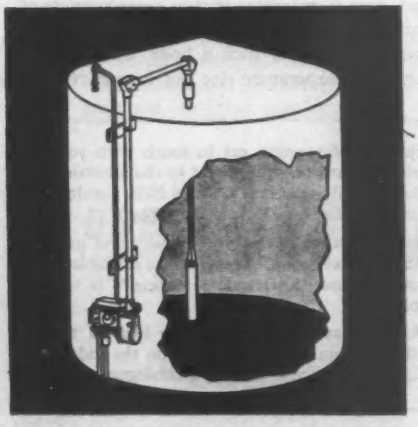
THE GILBARCO FIRTH CLEVELAND TANK GAUGE is a highly sensitive electronic device for local and remote indication of the level of liquids—or liquid interfaces—in deep tanks of all shapes and sizes. It gives continuous readings of level for liquids of any specific gravity and it is accurate within a few thousandths of an inch—this is particularly important in tanks with a large free surface area.

The instrument is suitable for use in hazardous areas and in extreme temperatures and it will operate data reduction or logging equipment. One remote indicator can be arranged to show the contents of up to 30 tanks in turn.

Routine maintenance can be carried out without taking the tank out of service.

These gauges are available to American Class I Group D Division I classification. We are shortly producing them to meet Buxton flameproof requirements.

The range of Firth Cleveland Instruments includes Electrical, Mechanical and Hydrostatic Tank Gauges, Pressure Operated Switches, and Pressure Relief Valves. We shall be happy to send you full particulars.



Made under licence to Gilbert and Barker Mfg. Co., U.S.A. *For full details write to:*

FIRTH CLEVELAND INSTRUMENTS LTD

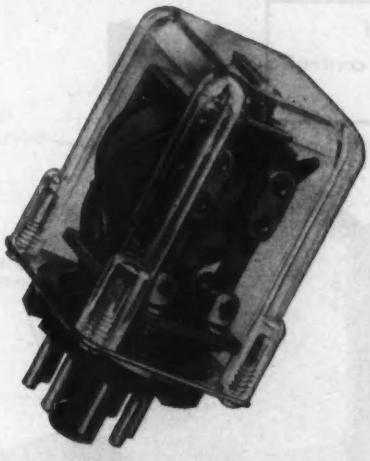
IFC STORNOWAY HOUSE, CLEVELAND ROW, LONDON, S.W.1. TELEPHONE: WHITEHALL 2166
A MEMBER OF THE FIRTH CLEVELAND GROUP

Branches: BIRMINGHAM · MANCHESTER · STOCKHOLM · COPENHAGEN · BALLARAT · SYDNEY JOHANNESBURG · NAARDEN · MILAN · BRUSSELS · MANNHEIM and NEW YORK.

CRC 29G

New...THORN PLUG-IN RELAYS

Thorn Pygmy Power Relay



New interchangable relay designed for use in remotely controlled automation units. Has double pole changeover contacts.

Dust proof—transparent plastic cover.

Plugs into any standard International octal valve base.

Weight Only 4½ ozs . . . projection only 2" above base.

Mechanical life over 10,000,000 operations.

Switching current: 5 amps maximum at 250 volts A.C.
Maximum surge current: 10 amps.
Operate time: 8 milliseconds approx.
Release time: 6 milliseconds approx.
Overall dimensions: 1⅜" square by 2$\frac{9}{16}$"
Coil voltage: 240 volts standard; also available for 6, 12, 24, 48, 60, 110 volts

Thorn T9 Micro-Switch Relay

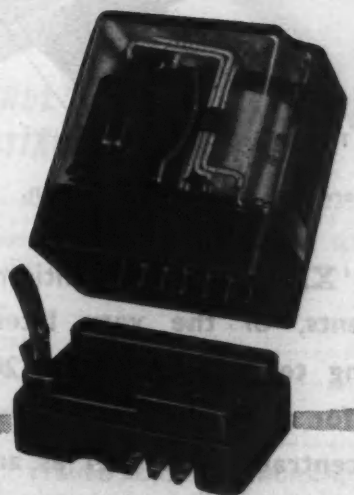
A plug-in relay, particulary suitable for switching P.A. equipment, the snap action contacts minimising interference with pick-up leads.

Operating coil wound for any specified voltage up to 240 volts A.C. or 150 volts D.C. May be tropicalised.

Up to three micro-switch pattern contacts mounted on standard coil frame.

Versions available with up to 11 solder tags or 10 screw terminals.

Contacts:	3 changeover.
Mechanical Life:	Over 10,000,000 operations.
C/O Time:	C.O. period less than 2 milliseconds.
Max. Switch:	10 amps/240 volts A.C. non inductive load.
Capacity:	0.2 amps/240 volts D.C. „ „ „ 0.5 amps/110 volts D.C. „ „ „ 1.0 amps/50 volts D.C. „ „ „ 5 amps/24 volts D.C. „ „ „
Max. Operate Speed:	20 cycles/sec.
Switching Frequency:	Up to 0.1 amp. approx. 20 cycles/sec. „ „ 1 „ „ 5 „ „ „ „ 5 „ „ 1 „ „ „ „ 10 „ „ 0.1 „ „ (referred to A.C. non-inductive load).



Thorn

THORN ELECTRICAL INDUSTRIES LIMITED

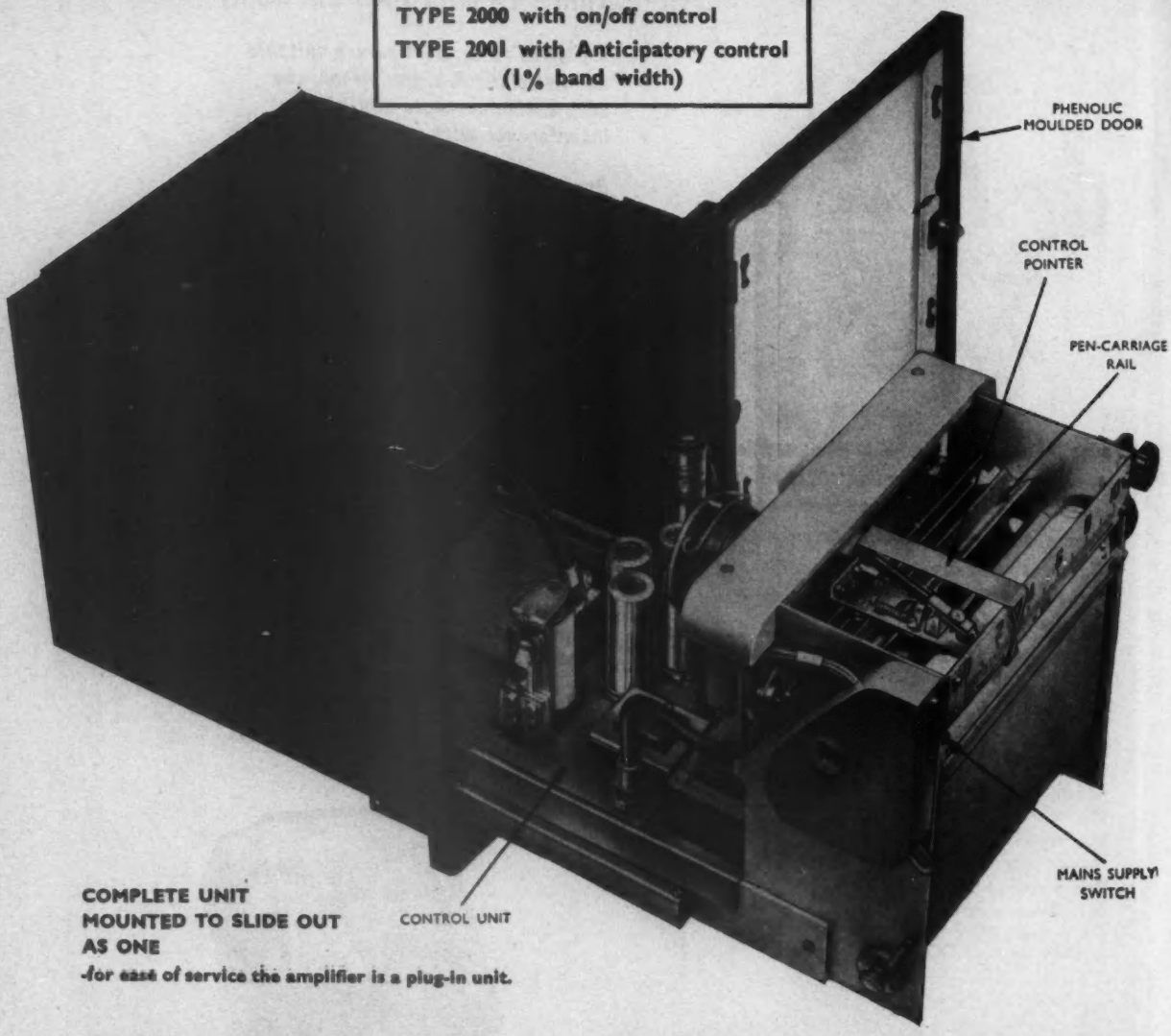
SPECIAL PRODUCTS DIVISION (INCORPORATING COMPONENTS & CONNECTORS)
GREAT CAMBRIDGE ROAD, ENFIELD, MIDDLESEX *Tel:* ENField 5353

ETHER 'XACTROL pr

(LIMITED)

Potentiometer Recording Controllers, SERIES 2000

TYPE 2000 with on/off control
TYPE 2001 with Anticipatory control
(1% band width)



COMPLETE UNIT MOUNTED TO SLIDE OUT AS ONE

-for ease of service the amplifier is a plug-in unit.

ETHER 'XACTROL' Potentiometer Recording Controllers are high-quality instruments, of the very latest design, for accurately controlling and measuring temperatures of — 200°C up to + 2,000°C. They are equally suitable for measuring variables such as speed, strain, pressure and hydrogen-ion concentration, as well as any other quantity that can be expressed as an electrical signal.

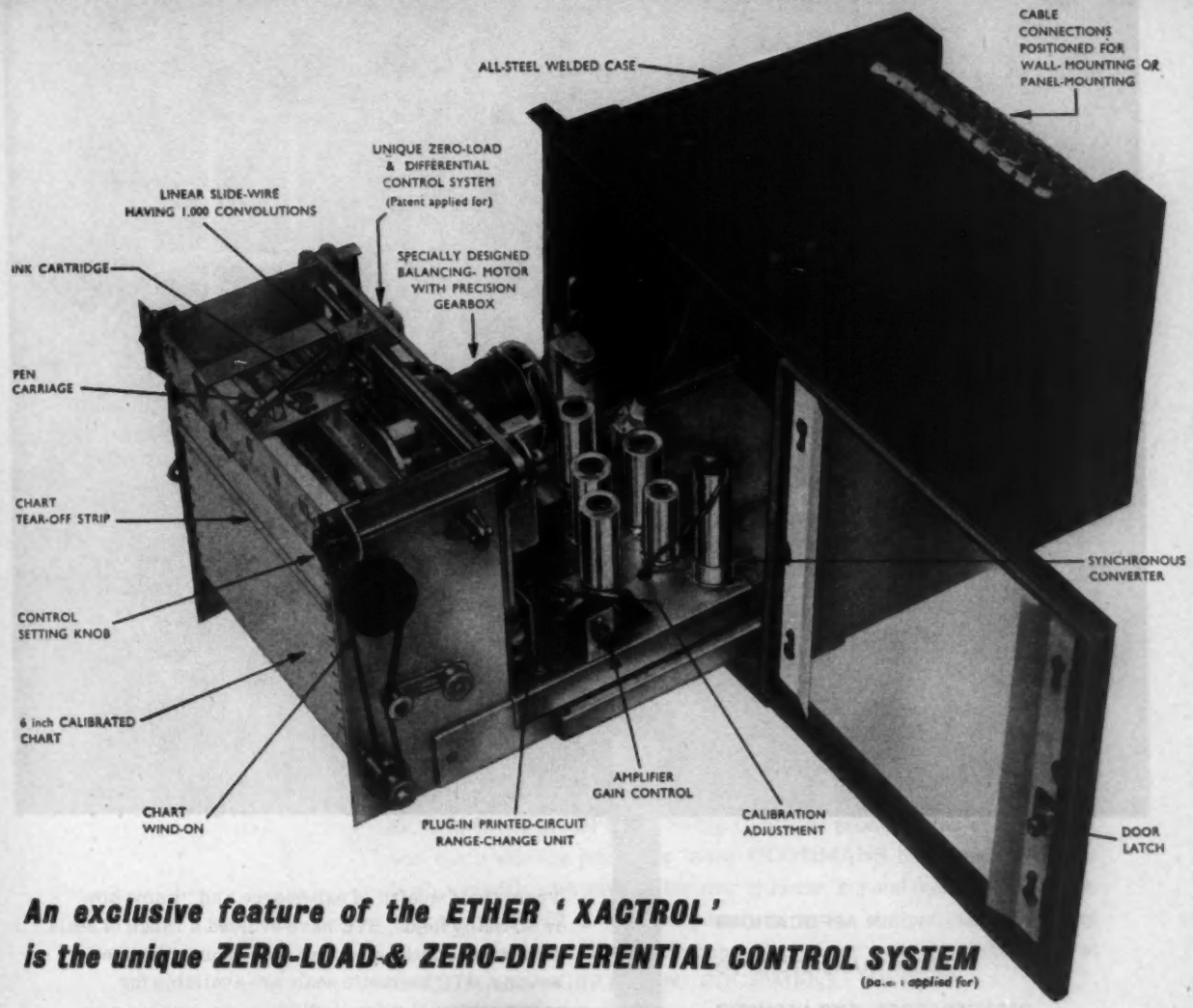
Circle No 25 on reply card for further details

* SIMPLICITY OF DESIGN * EASIER RANGE CHANGING * G

provide EVEN HIGHER STANDARDS OF PERFORMANCE

SALIENT FEATURES INCLUDE!

* Unique Zero-load & Zero-differential control system
* 6 calibrated scale * Small panel cut-out 10½" 9½"
* Patent Ink Cartridge * Front control-point setting



An exclusive feature of the ETHER 'XACTROL' is the unique ZERO-LOAD & ZERO-DIFFERENTIAL CONTROL SYSTEM
(patent applied for)

—which totally eliminates the use of mechanically-operated linkages and snap-action switches

- **ZERO-LOAD even at control point**
- **ZERO-DIFFERENTIAL**
- **WIPING-ACTION, continuously-cleaning contacts**
- **ADJUSTABLE OVER FULL SPAN**

from £125-0-0 delivered

FILL IN AND POST NOW

Please supply, without obligation, full details of the ETHER 'XACTROL.' C.10

FIRM .....

ADDRESS .....

.....

Attention of .....

ETHER LIMITED

TYBURN ROAD BIRMINGHAM, 24 (East 0276-8)
CAXTON WAY, STEVENAGE, HERTS (Stevenage 2110-7)

REPRESENTATIVES THROUGHOUT THE U.K.
AGENTS IN ALL PRINCIPAL COUNTRIES

*GING * GREATER ACCESSIBILITY * EASIER SERVICING & INSPECTION*

STC hermetic seals

IN APPLICATIONS FROM TRANSISTORS TO REFRIGERATORS, **STC** HERMETIC SEALS HAVE PROVED THEIR PERFORMANCE AS HIGH GRADE COMPONENTS

From their wealth of experience and "know how" in so many fields, STC have evolved a range of seals to meet the most exacting standards of hermetic sealing. STC hermetic seals are available for many applications including:
Lead through insulators with flexible or solid terminations for transformers, relays etc.
Crystal base seals. Refrigerator seals.
End seals for cylindrical components.

Write for publication No. MK/153 which gives details of these and other STC Hermetic Seals.

STC COMPONENTS GROUP

60/8MK

Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, London, W.C.2

TRANSISTOR DIVISION: FOOTSCRAY · SIDCUP · KENT

$$\frac{df}{dt} = \frac{1}{70} f^{\frac{4}{3}}$$

Resolved by the E502

SWEEP OSCILLATOR

The Sweep Law $\frac{df}{dt} = \frac{1}{70} f^{\frac{4}{3}}$ baffled the Electronics Industry until the GOODMANS Model E 502 Sweep Oscillator produced the answer. That was but a starting point, for today GOODMANS have made available further models with sweep constants to linear, log and other complex laws. The Model E 502 is but one instrument in the comprehensive range of Electronic Control and Measuring Equipment now in production at GOODMANS VIBRATION EQUIPMENT DIVISION.

Whatever your vibration problem, whether fatigue, torsional or flexure testing or structural investigation, consult the Vibration Specialists first.

GOODMANS

For full details of the complete range of Goodmans Vibration Equipment, post this coupon.

GOODMANS INDUSTRIES LIMITED
Axiom Works, Wembley, Middlesex, England.
Please send me a copy of your Vibration Equipment Catalogue.

NAME _____

ADDRESS _____

_____

GD61

GOODMANS INDUSTRIES LIMITED, AXIOM WORKS · WEMBLEY · MIDDX · ENGLAND
Telephone: WEMbley 1200 (8 lines) Cables: Goodaxiom, Wembley, England.

Why it will pay you to study the possibilities of the

Conflex
P.V.C. P.T.F.E.
Reg'd. Trade Mark

CONDUIT SYSTEM

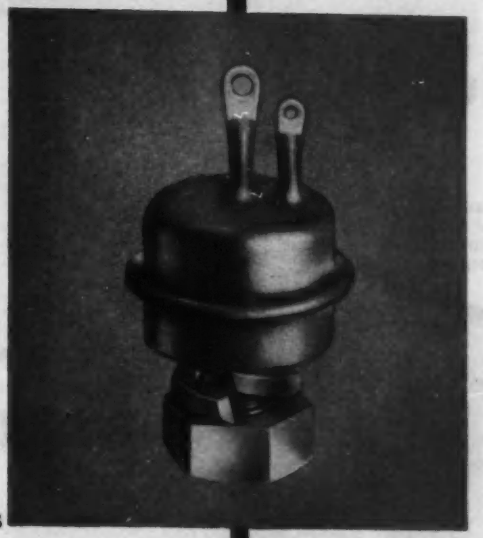
- Substantial saving in weight
- High degree of flexibility—no metal fatigue
- Terminations fit British and American connectors, junction boxes, etc.
- Withstands temperatures from —70°C to +240°C—continuous rating
- Provision for pressure sealed electrical system
- Eliminates special cable lays, moulded harnesses, and problems involved in encapsulation
- Simplifies connector wiring and permits easy conductor changes
- Assembly *in situ* requires no special tools
- Provision for double-screening on R.F. circuits
- Conduit unaffected by ester-based fluids

If you are interested in any of these design features you cannot ignore the Superflexit patented 'Conflex' Conduit System now being widely used by leading Electronic Manufacturers.

ASK US TO LOOK INTO YOUR PROBLEM —TODAY!

SUPERFLEXIT LTD • BUCKINGHAM AVENUE • SLOUGH • BUCKS

AEI
Silicon Controlled Rectifiers
NOW IN QUANTITY PRODUCTION



Some of the applications:

- ★ Motor Control
- ★ D.C.-A.C. conversion
- ★ Frequency conversion
- ★ Phase-controlled D.C. power supply
- ★ Static switching
- ★ Ignition firing and numerous other applications in the aircraft, instrumentation and process control fields

Ratings

Rectifier Type:	Peak inverse voltage volts	Mean D.C. forward current amp.	Typical Trigger power mW	Rectifier Type:	Peak inverse voltage volts	Mean D.C. forward current amp.	Typical Trigger power mW
CR10.C21-A	25	10	50	CR5.021-A	25	5	50
CR10.C51-A	50	10	50	CR5.C51-A	50	5	50
CR10.071-A	75	10	50	CR5.071-A	75	5	50
CR10.101-A	100	10	50	CR5.101-A	100	5	50
CR10.151-A	150	10	50	CR5.151-A	150	5	50
CR10.201-A	200	10	50	CR5.201-A	200	5	50
CR10.251-A	250	10	50	CR5.251-A	250	5	50
CR10.301-A	300	10	50	CR5.301-A	300	5	50

Write for full details to:

AEI

Associated Electrical Industries Limited

Electronic Apparatus Division

VALVE AND SEMICONDUCTOR SALES
LINCOLN, ENGLAND

AS512

JLT
instruments for **industry**

Type BP3
For High Pressures
up to 20,000 p.s.i. Wide frequency response aids transient measurements in hydraulic and pneumatic systems.

for the measurement of

HIGH..

Type UP
For Medium Pressures
up to a maximum of 1000 p.s.i. For rapidly fluctuating or steady pressures, having response to transients up to 3000 c.p.s.

MEDIUM..

LOW
pressure

This selection from the range of JLT Transducers will convert air, gas or liquid pressures into equivalent electrical outputs of sufficient strength to drive recorders and indicators. By introducing a suitable JLT Diaphragm Isolator, corrosive fluid or gas pressures can also be measured. They have many applications in the chemical and aircraft industries, in addition to a wide variety of industrial undertakings.

Type SB
For Low Pressures
below 20 p.s.i. or 30 inches Hg vacuum. Suitable for steady and slowly varying pressures. Direct current output to drive recorder.

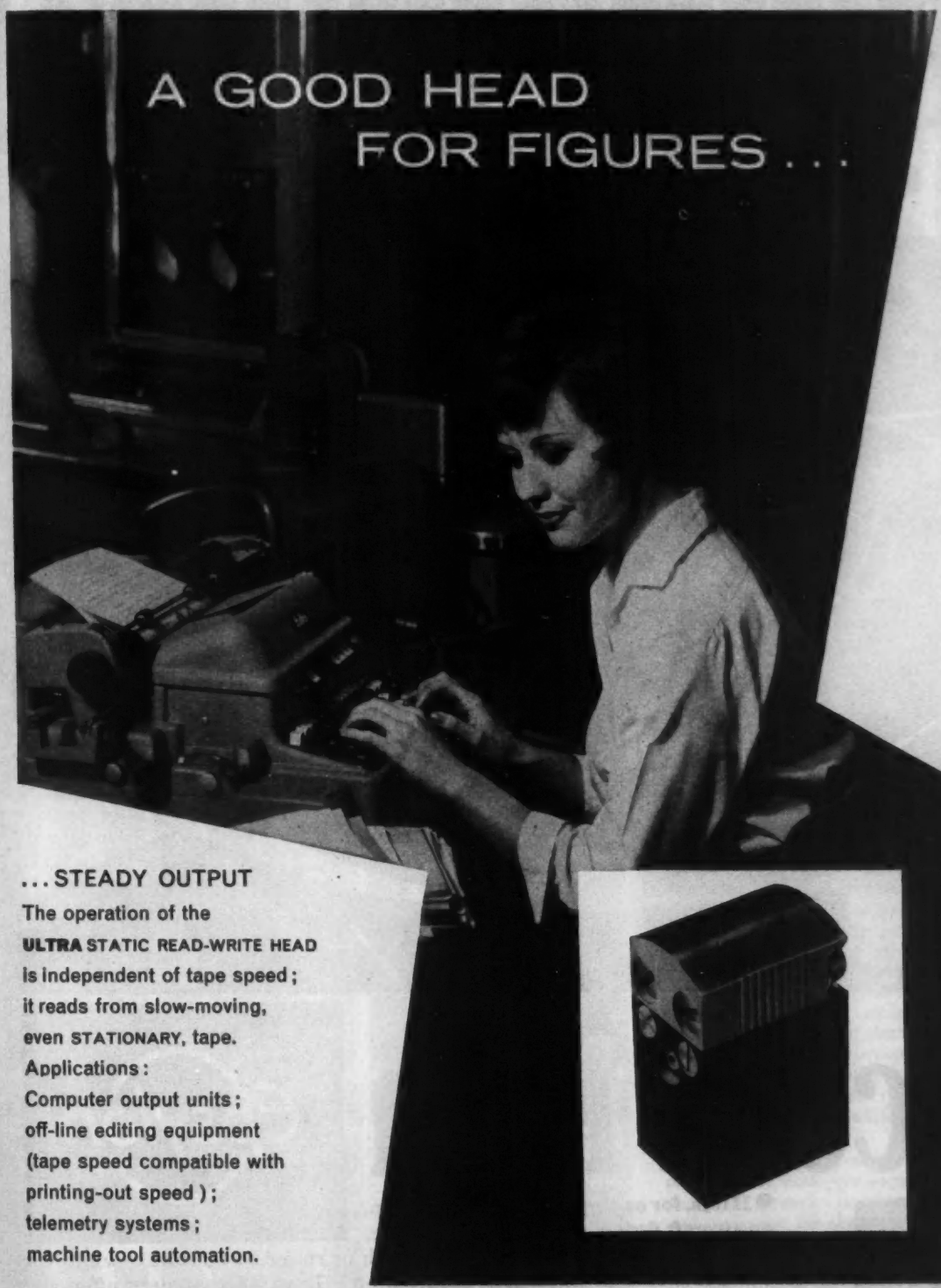
JLT GROUP

J. LANGHAM THOMPSON LTD

BUSHEY HEATH · HERTFORDSHIRE · ENGLAND

Telephone: BUShey Heath 2411 (6 lines) Grams & Cables: 'Tommy Watford' T/1

A GOOD HEAD FOR FIGURES . . .



. . . STEADY OUTPUT

The operation of the **ULTRA** STATIC READ-WRITE HEAD is independent of tape speed; it reads from slow-moving, even STATIONARY, tape.

Applications:
Computer output units;
off-line editing equipment (tape speed compatible with printing-out speed);
telemetry systems;
machine tool automation.

In the background: PEGASUS. By courtesy of Ferranti Ltd.

ULTRA

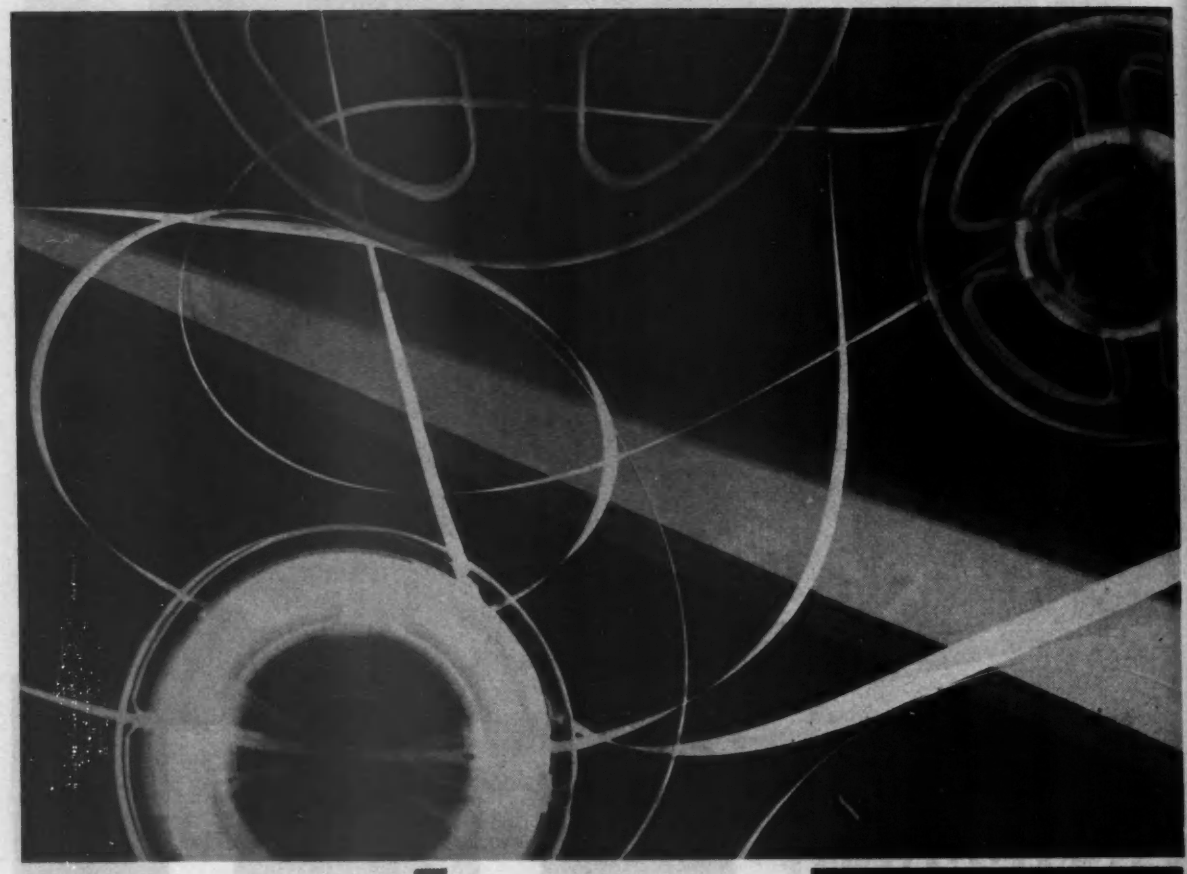
Please send for brochure

ULTRA ELECTRONICS LIMITED

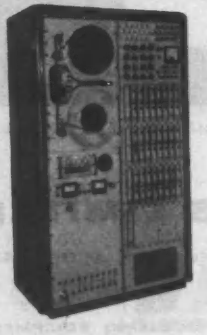
WESTERN AVENUE · LONDON · W.3 · Telephone: ACOrn 3434

RADIO AND RADAR SYSTEMS · AIRCRAFT ENGINE CONTROLS & INTERCOMM · DATA PROCESSING EQUIPMENT

If it accelerates



record it on Epsylon

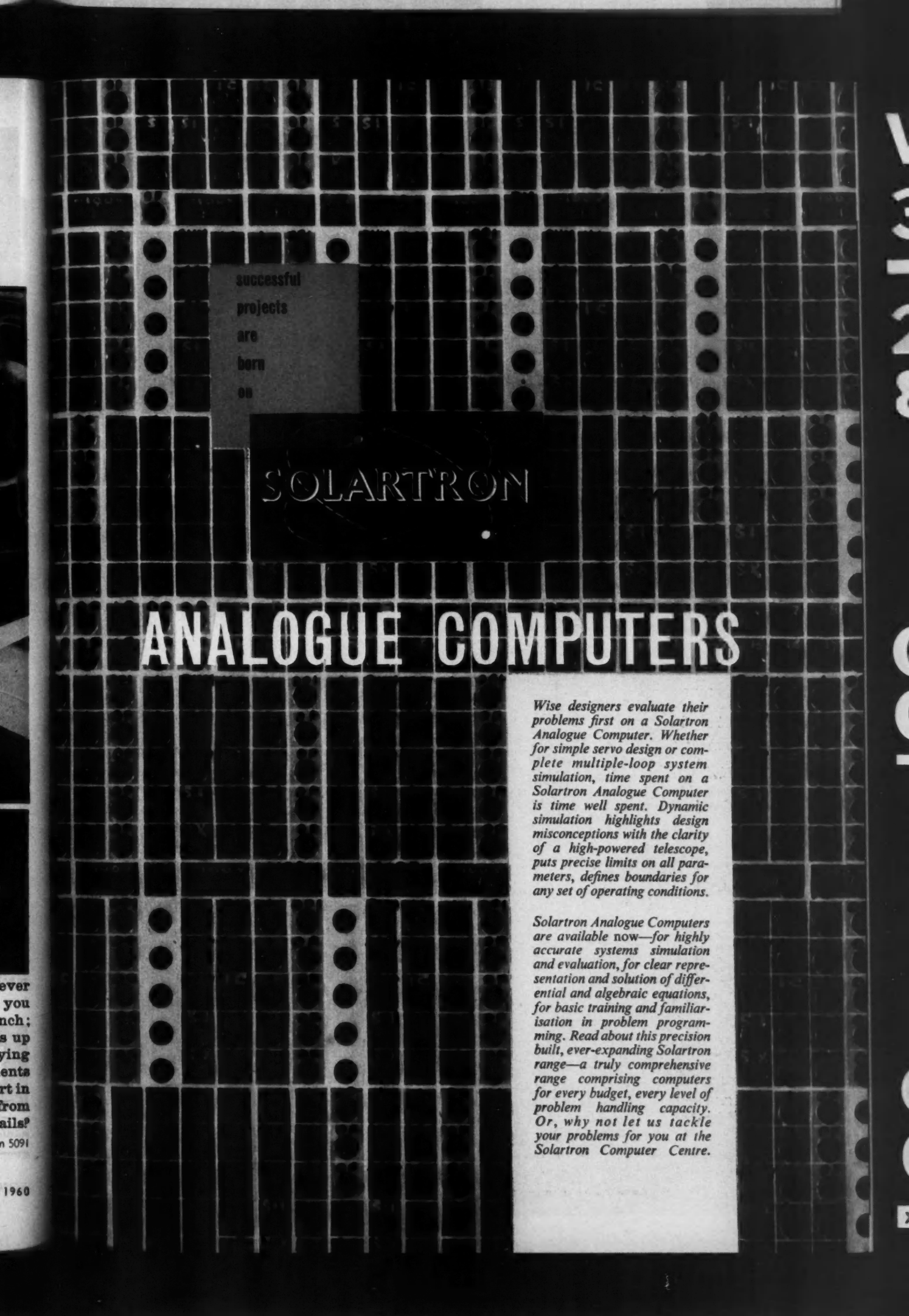


An 11-speed multi-channel recorder

● If it is, for example, a rocket going up, an aircraft flying, a vehicle going along, or a machine part going back and forth or round and round—whatever its speed, rate of acceleration, direction—Epsylon recorders offer you the most advanced recording facilities: up to 16 channels per inch; frequency DC to 200 kc/s; capacity 5,000 ft.; a range of tape speeds up to 150 ins./sec.; endless loop; remote control; recording and replaying at different speeds; fixed and mobile models. Epsylon instruments record physical conditions, digits and sound, and can play a key part in a variety of applications, ranging from research to prospecting; from electronic computors to music in aircraft. May we send you full details?

EPSYLON INDUSTRIES LTD Faggs Road, Feltham, Middlesex, England. Telephone: Feltham 5091

A member of the Stone-Platt Group


successful
projects
are
born
on
SOLARTRON
ANALOGUE COMPUTERS
Wise designers evaluate their problems first on a Solartron Analogue Computer. Whether for simple servo design or complete multiple-loop system simulation, time spent on a Solartron Analogue Computer is time well spent. Dynamic simulation highlights design misconceptions with the clarity of a high-powered telescope, puts precise limits on all parameters, defines boundaries for any set of operating conditions.
Solartron Analogue Computers are available now—for highly accurate systems simulation and evaluation, for clear representation and solution of differential and algebraic equations, for basic training and familiarisation in problem programming. Read about this precision built, ever-expanding Solartron range—a truly comprehensive range comprising computers for every budget, every level of problem handling capacity. Or, why not let us tackle your problems for you at the Solartron Computer Centre.

SOLARTRON

training

research

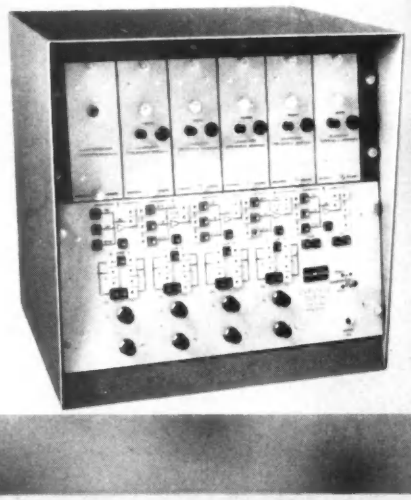
full scale

any size

4 ad infinitum

1 analogue tutor

Capable of demonstrating any form of second-order differential equation. Applications include representation of servos, simple electrical networks, motion of particles and like systems.



* A complete miniature computer for Student use

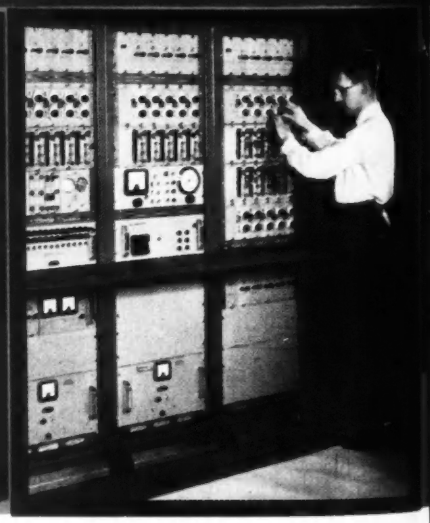
AMONG THE USERS OF SOLARTRON COMPUTERS ARE

A.E.I. (Heavy Plant Divisio
British Nylon Spinners
English Electric
G.E.C.
Hawker Siddeley Group
I.C.I.
C. A. Parsons
Royal Aircraft Establishment
U.K.A.E.A.
United Steel

It is safer and cheaper to simulate mistakes than make them. Without having to build it, here is your projected syste brought to your very desk-side or laboratory!

The Solartron SPACE '30' analogue computer (right) is unique in flexibility of application. With an operational capacity greater than many computers using 40 or more amplifiers, SPACE '30' has an additional problem-beating complement of non-linear units for direct analogue simulation of almost any dynamic system. Even when many complex system elements must be included as analytic or empirical non-linear operators, SPACE '30' will faithfully simulate according to the known information to produce a highly accurate prediction of dynamic performance.

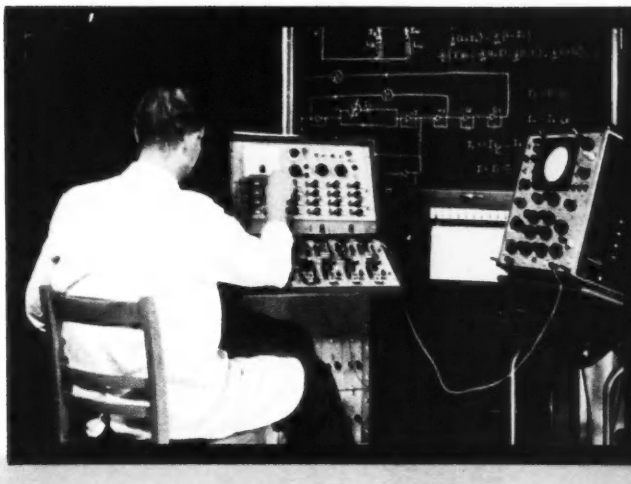
All Solartron analogue computers are built using a highly flexible modular construction technique. Thus at any time, your Solartron machine need only be as complex as budget and work demand. Special machines, like the Auto-Control Simulator illustrated here, or the SPACE '30' series, can be expanded or multiplied at a moment's notice.



ANALOGUE COMPUTERS

The Analogue Computer is the foremost aid to training in feedback techniques and theoretical servo analysis, also for clearly representing and solving complex differential equations.
Because of its common basic approach to all dynamic problems, analogue computing practice is vital to broadening engineering appreciation. Parallels between widely different systems are drawn with sudden lucidity — between hydraulic controls and national economics for example, or between a nuclear reactor and a controlled biological culture. Every problem solved on an analogue computer brings a wealth of dynamic knowledge, relevant to wide areas of subsequent work.

MINISPACE * Provides high accuracy at low cost * Ideal for servo simulation and basic reactor studies for students. * Eminently suitable for sub-programming larger machines.

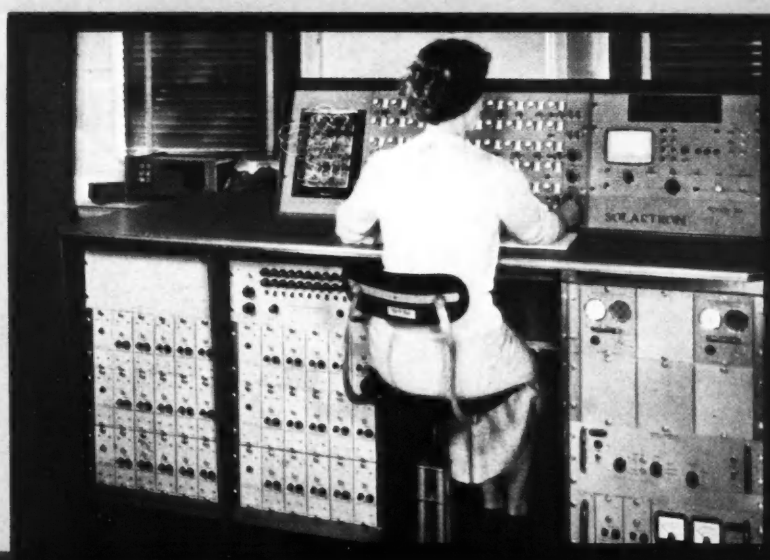


2 minispace

★ Solves linear or non-linear problems: up to 5th-order differential equations.

★ Easily expanded to greater problem capacity.

For handling even bigger problems, your SPACE '30' installation can be multiplied to give 60 or 90-amplifier capacity—or, in the preferred case, you can choose a SPACE '60' or SPACE '90' machine, each fully integrated for centralised programming and control.



3 space '30'

★ 30 amplifiers in new, optimised design configuration.

★ Full complement of non-linear computing elements.

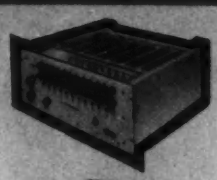
★ The first choice for complex dynamic simulation of any kind.

★ Easy to use — easily expanded.

FOR INDEPENDENT USE

These three Solartron Analogue Computing Units are typical of many which exist in their own right as precision instruments and which are immediately available for use independently, or in existing analogue computing installations.

Full technical literature is available on request.

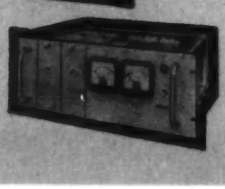


- 12-Segment, high accuracy function generation. ± 100 V output, 0.5% long-term stability.
- Rapid, accurate break-point setting in Cartesian co-ordinates, by digital volt-meter.

5 diode function generator TR 829

- Fastest response available: accurate f.s.d. up to 10 c/s.
- Six-section pot, driven directly from servo.
- Self-contained with transistor feedback amplifier and power supply.
- Multiplies up to five variables by one other or generates up to sixth power.

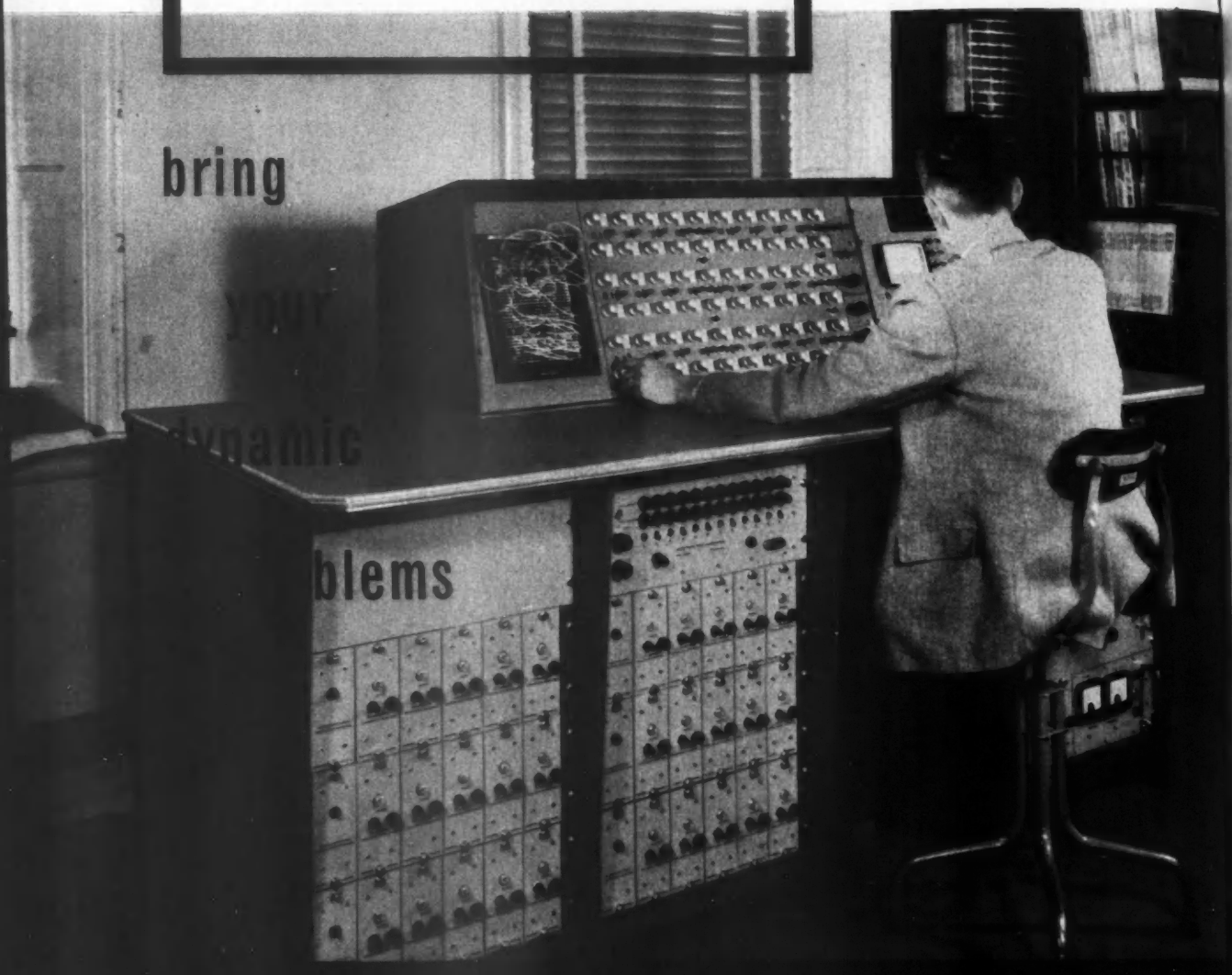
6 servo multiplier TJ 725



- 0.005% limit on deviation between positive and negative 100V supplies. NPL certificate on request.
- Better than 0.1% long term accuracy and 4,000 to 1 stability ratio.
- Incorporates Weston cell as reference source.

7 precision reference power supply AS 756/2

THE SOLARTRON Computer Centre at the Dorking Research and Development Laboratories of the Solartron Group offers comprehensive facilities for dynamic problem evaluation, programming and detailed solution on SPACE '30' Analogue Computers. Skilled personnel will, if you require, translate your problems into computer language and carry out all the operational procedures.



SOLARTRON COMPUTER CENTRE

address your enquiries to :

THE SOLARTRON ELECTRONIC GROUP LIMITED (Computer Division)
Victoria Road, Farnborough, Hampshire. Telephone: Farnborough (Hants) 3000

GREAT NAMES THINK ALIKE
they choose Baldwin
Atomat Nucleonic Thickness Gauges

Look on the machines turning out some of Britain's most famous products and you'll find Baldwin Nucleonic Gauges saving material, labour and time! Yet, although Baldwin gauges are used more and more throughout industry, there's no question of a standard unit for all machines. Baldwin gauges are—and always will be—tailored individually to the measuring job in hand.

SO THAT'S POINT ONE . . . **BALDWIN DESIGN AND MAKE COMPLETE CONTROL GAUGE SCHEMES FOR SPECIFIC INSTALLATIONS**

Then there's Baldwin Automatic Standardisation and Control. Baldwin gauges not only check materials in production, but can correct the machine when production limits are exceeded. And Baldwin gauges *even check themselves*, automatically compensating for any radioactive source decay.

AND THAT'S POINT TWO . . . **CONSTANT INSPECTION — CONSTANT ASSURED ACCURACY**

ADD THESE OTHER POINTS AND IT BECOMES OBVIOUS WHY BRITAIN'S TOP MANUFACTURERS CHOOSE BALDWIN

* **SAVINGS IN TIME AND MATERIAL**
* **CALIBRATION IN YOUR USUAL UNITS OF MEASUREMENT**
* **HIGH ACCURACY**
* **MINIMUM MAINTENANCE**

Ask Baldwin for their brochure C-124; it carries clear and concise information—but no obligation on your part.

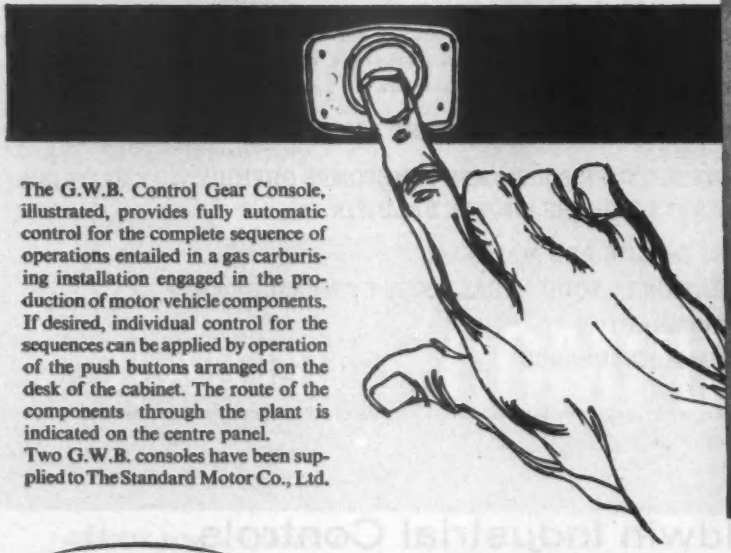
INSTRUMENT DIVISION

Baldwin Industrial Controls

Baldwin Instrument Company Ltd., Dartford, Kent
Telephone: Dartford 20948 & 28411 Cables & Telex: Baldwin, Dartford
A HARPER GROUP COMPANY

STANDARD TRIUMPH

USE G.W.B. CONTROL GEAR



The G.W.B. Control Gear Console, illustrated, provides fully automatic control for the complete sequence of operations entailed in a gas carburising installation engaged in the production of motor vehicle components. If desired, individual control for the sequences can be applied by operation of the push buttons arranged on the desk of the cabinet. The route of the components through the plant is indicated on the centre panel.
Two G.W.B. consoles have been supplied to The Standard Motor Co., Ltd.

GWB

G.W.B. FURNACES LIMITED (CONTROL GEAR DIVISION)

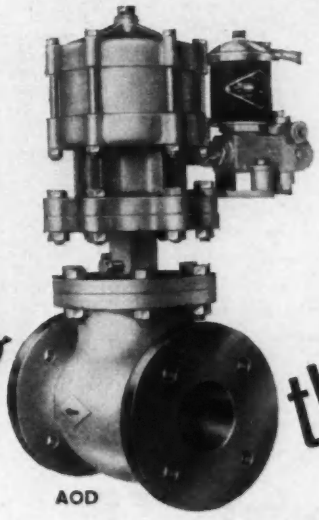
P.O. BOX 4 · DIBDALE WORKS · DUDLEY · WORCS *Telephone: Dudley 55455 Grams: Gibwildbar, Dudley Telex: 33188*

ASSOCIATED WITH GIBBONS BROS. LTD., AND WILD-BARFIELD ELECTRIC FURNACES LTD.

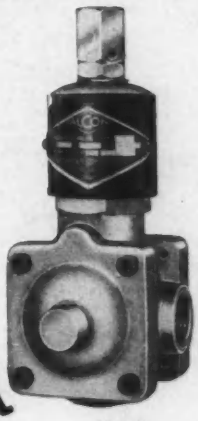
C.W.B. 257

ACH

anything that flows



AOD



SPC 3

ACO

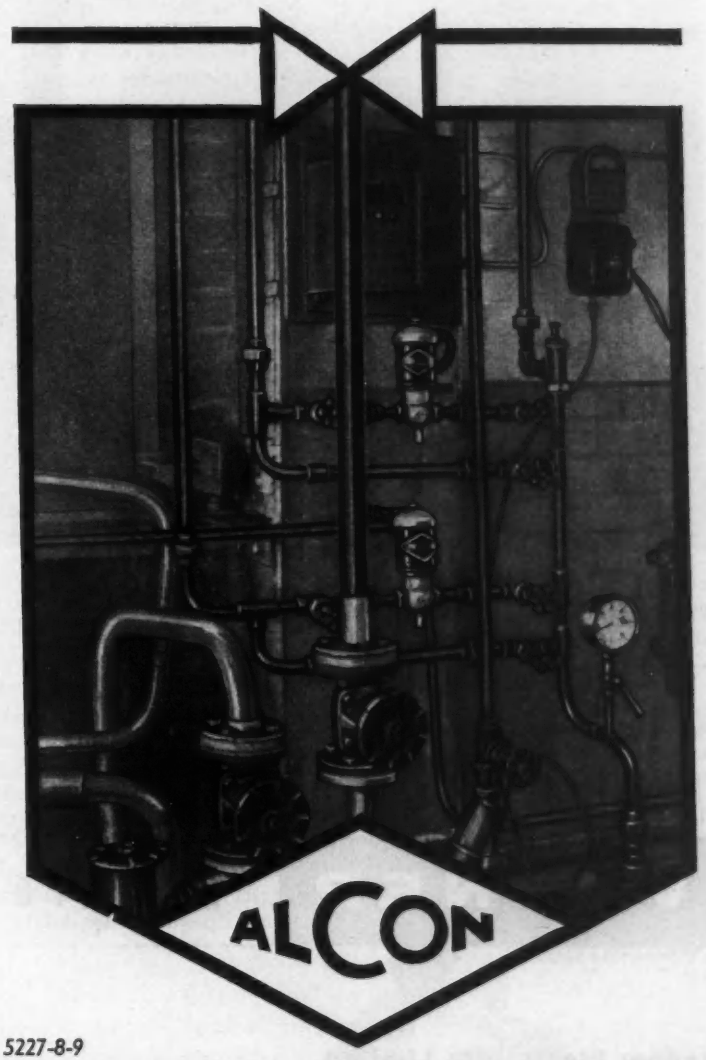
All Liquids and Gases can be positively controlled by an Alcon Solenoid or Air-Operated Valve. Sizes from ⅛" B.S.P. to 8" Bore. Pressures up to 1,500 p.s.i. Temperatures up to 300°C. Body materials to suit all media including corrosive acids, with Standard, Weatherproof or Buxton Certified Flameproof Solenoid Housings. Glandless, Fluon Glands or Stainless Steel Bellows Glands.

AIR-OPERATED Type AOD—Heavy duty air operated units individually designed for control applications beyond capabilities of Solenoid types. For pressures up to 1,500 p.s.i. Sizes ¼" B.S.P.—8" Bore.

SPC.3—Three-way valves for electro-pneumatic control systems. Sizes up to ½" B.S.P. for use with air up to 150 p.s.i.

MIDGET Type ACO—Sizes up to ¼" B.S.P., used for control of air, gases, water, oil at pressures up to 300 p.s.i. Single way—Reverse acting—Three-way types available.

ACH—Hand Reset type, closing automatically on current failure, for low and medium pressures. Sizes from ¾" B.S.P. to 6" Bore. Inexpensive, simple construction, reliable in operation. Also available type ACHL. Lever operated for use with steam, hot water and pre-heated fuel oils.



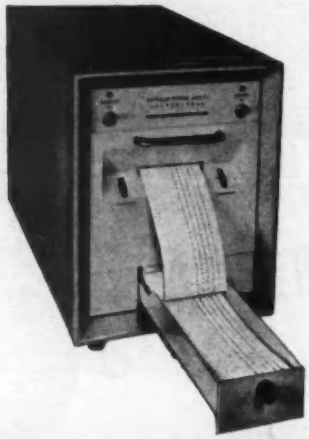
'Phone : SUTton Coldfield 5227-8-9

ALEXANDER CONTROLS LTD., REDDICAP HILL, SUTTON COLDFIELD, WARWICKSHIRE

A MEMBER OF THE CONCENTRIC GROUP OF COMPANIES

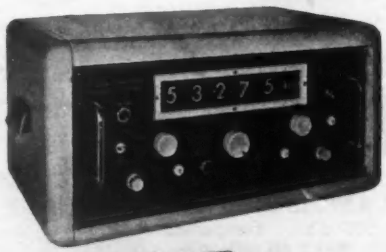
Transistorized Printer TSA 65

A high-speed parallel entry Printer capable of speeds up to 5 lines/sec. Inputs for 11 print wheels are provided. The Printer can be driven by the decimal output readily available from our in-line readout counters, or by meter readout instruments using TS11 decade selectors.



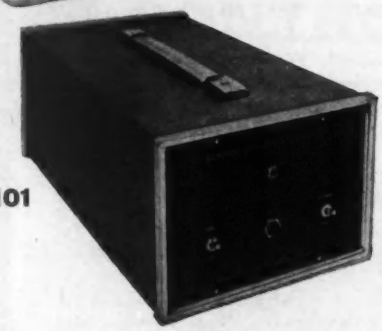
Transistorized Frequency and Time Measuring Equipment TSA 1135

This instrument is equipped with in-line readout . . . a clear, unambiguous display, legible from a distance of 30 feet. It is capable of a wide range of operations, among them period measurement to 10 kc/s, time measurement to 999,990 secs, frequency measurement up to 100 kc/s (standard) or to 1 Mc/s (type 1135/P). Outputs can be provided for the TSA65 printer or TSA101 Reperforator Control Unit.



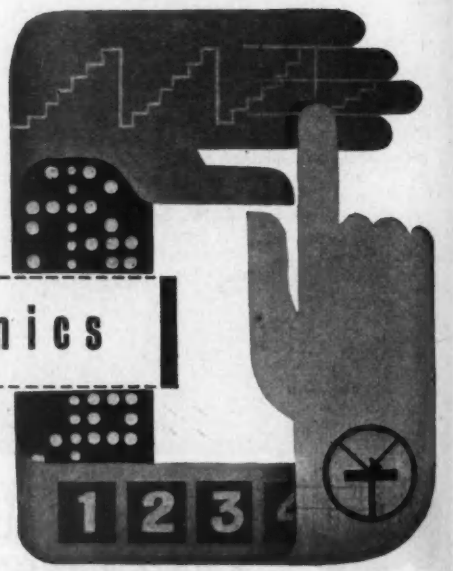
Transistorized Reperforator Control Unit TSA 101

Designed to drive 5 hole Reperforators at 11 out of 15 punching stations per cycle (automatic sequencing). The Reperforator mechanism is driven entirely by transistor circuits, each of which is made up as a plug-in stage.



Three Venner instruments designed to facilitate the presentation of information, emblematic of the versatility of Venner electronic equipment.

Our new 'short form' catalogue is a concise guide to the whole range. A note on your company letterhead will bring a copy by return of post.



VENNER Electronics

Venner Electronics Limited,
Kingston By-Pass, New Malden, Surrey
MALden 2442 *A member of the Venner Group of Companies*

What's your yearly print bill, Bill?

But when I told him, he wouldn't believe me. So I explained about our Gestelith, how we trained up a girl from the accounts department and had her turning out stuff from paper plates we typed ourselves before we'd had the machine 24 hours. "But that's not the point", he said. "I'm talking about *print*, not duplicating". That's *exactly* the point, I said, because while the machine pays for itself as a duplicator, our girl goes on to take over all our small printing, job by job... internal forms, stationery, letterheads, price lists, catalogues, even. "Sounds good", said Jim, "but would it suit me?" That's for you to say, I said. Why don't you ask for a demonstration? They're very helpful, these Gestelith people.

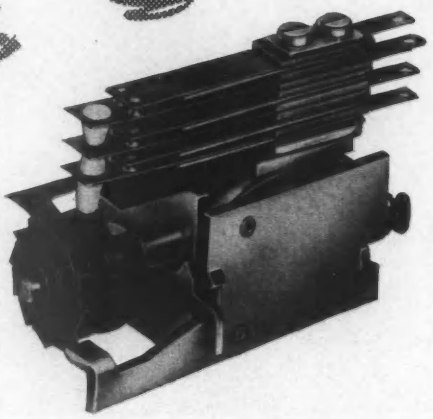
Operating routine of the Gestelith . . . most advanced of all small offset machines . . . has been designed on work study principles to reduce operator movement and to cut the number of mechanical operations to the minimum. A lot of the purely manual skill normally demanded of an offset operator has been built into the machine.

GESTELITH DISTRIBUTORS LIMITED
210 Euston Road, London, N.W.1 EUSton 3238/9
Gestelith is a division of the Gestetner World Organisation

Circle **No 42** on reply card for further details

No woman would act this way about a Relay unless...

It's a TMC ZETTLER RELAY and she's an electrical engineer



Well . . . we can't vouch for the woman. But we can for the Relay. It's one of the wide range commanding attention by offering decided advantages in every aspect of industrial control involving electrical and electronic equipment.
To be specific, it is the—

TMC ZETTLER (DIVIDE-BY-TWO) RELAY

TYPE AZ170

. . . a unique latching relay for the operation and release of contacts on successive pulses of the same polarity. A cam wheel is stepped at each operation of the armature by means of a ratchet and pawl mechanism. The contour of the cam is such that a simple springset is operated and released on successive operations. *This makes it a "divide-by-two" relay — its essential feature.* The armature is hinged on captive ball bearings for maximum reliability. Twinned, gold-flashed contacts have up to two change-overs and operating coils up to 110 volts D.C. It is particularly useful for remote control switching.

The wide range of TMC ZETTLER RELAYS is capable of handling power from microwatts to kilowatts. Extreme compactness is achieved in most cases. Where space is limited, their choice is destined to become a matter of course.

TMC ZETTLER RELAYS EXTEND THE ALREADY WIDE TMC RANGE AND MAKE TMC BEST EQUIPPED TO MEET YOUR RELAY REQUIREMENTS

TMC

Write now for further information.
Relay Division C
Telephone Manufacturing Company Limited
Hollingsworth Works, London, SE21. Telephone: GIPsy Hill 2211

NEW ZT20

FERRANTI introduce a high frequency double diffused MESA transistor

THE ZT20 IS THE FIRST OF A WIDE RANGE OF SILICON TRANSISTORS TO BE MADE BY

Ferranti

FERRANTI LTD · GEM MILL · CHADDERTON · OLDHAM · LANCS · Telephone MAIn 6661

London Office: Telephone: TEMple Bar 6666

FE 203

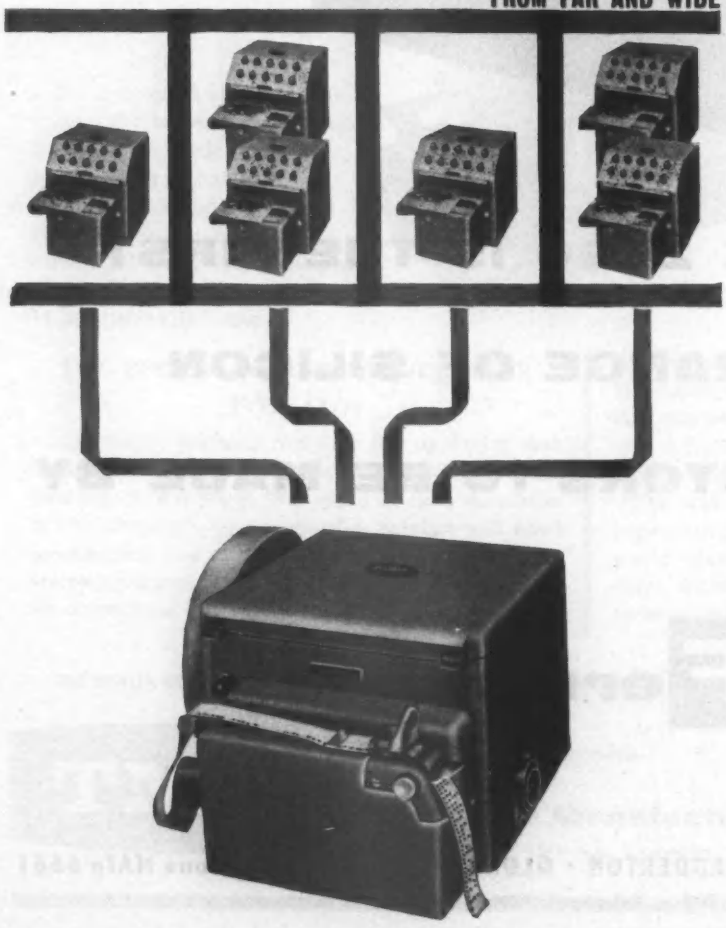
Circle No 44 on reply card for further details

FRIDEN COLLECTADATA

TAPE OPERATED EQUIPMENT

COLLECTS THE FACTS

FROM FAR AND WIDE



This latest range of FRIDEN IDP equipment will collect data from any number of points and punches it onto tape at a data processing centre. The FRIDEN 8 channel tape code is used throughout the system, which consists of two basic units; the *transmitter*, which can be designed to read either tape and edge punched cards, or tabulating cards, and is connected by common cable to the *receiver;* which punches tape and may be fitted with a Time Code Emitter to record on the tape the time each transmission is received.

The great advantages of this system are its speed, simplicity, and freedom from those inevitable transcription errors of manual recording and collection of data. Amongst its other important features are: provision at the transmitter for identification of each type of transmission; checking at the receiver for odd parity of each code as it is punched, which results in automatic operation of an Error Indicator on the transmitter calling for repeat transmission; a Line Busy Indicator on the transmitter which suspends operation, and automatically allows transmission when the line is clear; transmission will not commence should a data card be wrongly inserted; a special code at the end of a card 'holds' the line clear for any further transmissions required; up to 18 digits of variable data may be set up on the transmitter itself, to be sent whenever a transfer code is read. The scope of the FRIDEN COLLECTADATA is enormous, and any attempt to detail its applications here would be quite impossible. Three of the most significant are Production Control, Time Recording and Stock Control, but anyone conversant with the executive and administrative operations of commerce and industry will envisage many other potential fields of use.

BULMERS

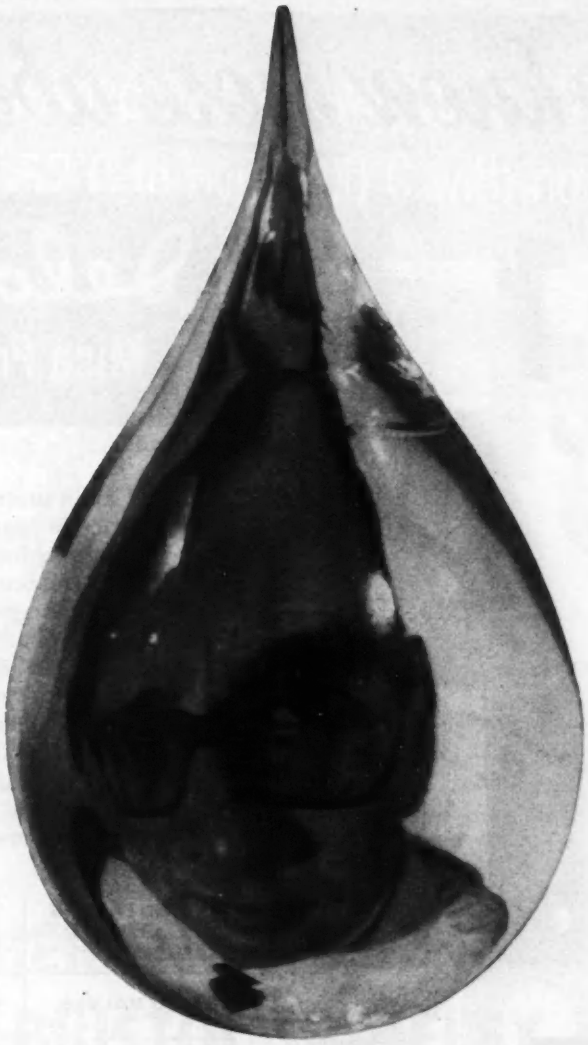
BUSINESS MACHINES LTD

BULMERS have now attained a leading position in this sphere of IDP, and their team of specialists is at your disposal, for general discussion or to advise on any specific problem. Please write to arrange an appointment or to obtain full details of 'COLLECTADATA' and other FRIDEN IDP equipment;

Bulmers Business Machines Ltd., 47-51 Worship St., London EC2. Tel: MON. 9791.

DTV 827

Circle No 45 on reply card for further details



LOOKING FOR FLUIDS—with exceptional thermal stability—fluids that are water-repellent and retain good dielectric characteristics over a wide range of temperatures — that resist oxidation—have low volatility and show little change in viscosity with temperature —are ideally suitable for use in damping mechanisms—as heat transfer media—and for use in hydraulic, springing and coupling devices—GET THEM FROM MIDLAND SILICONES.

Remember—Midland Silicones Ltd have consistently set the pace for British progress in this fast developing field. Remember, too, that—while silicones cost more initially—this extra outlay is more than offset in terms of greater efficiency and long term economy.

(MS) MIDLAND SILICONES LTD

(Associated with Albright & Wilson Ltd and Dow Corning Corporation)

***first** in British Silicones*

68 KNIGHTSBRIDGE · LONDON · SW1 · TEL: KNIGHTSBRIDGE 7801

Area Sales Offices: Birmingham · Glasgow · Leeds · London · Manchester · Agents in many countries

The full range of MS silicone fluids is described in detail in our new 'Engineering Guide to MS SILICONE FLUIDS.' Just complete the coupon and we'll be glad to send you a copy.

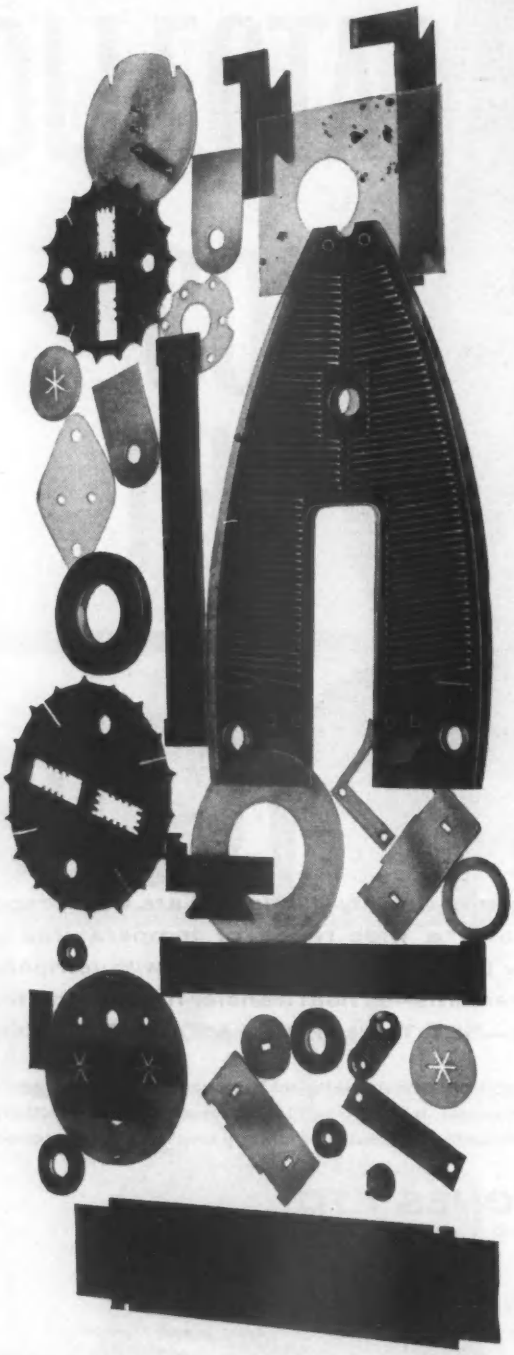
NAME _____

COMPANY _____

ADDRESS _____

MSF 1

Get to know more about



Delanco REGD.
Mica Products

Get to know more about the Delanco Mica service. We can assist you in the choice of grade and type most suitable for the purpose required, and give the best possible service and attention to your requirements. We have our own well equipped tool sections staffed by operators who know, from years of experience, the most efficient methods of dealing with the various grades in this medium and extreme accuracy of tooling.

COMMUTATORS.	Mica segments. Commutator end segments.
LAMPS.	Mica Baffle plates.
RADIO VALVES.	Mica valvebridges to the very close tolerances needed.
HEATING ELEMENTS.	Wire wound mica elements, Mica washers, separators, Flexible Mica.
SWITCHGEAR.	Built up Mica washers.
RADIO AND TV.	Mica washers, Mica Trimmer plates.
ELECTRIC IRONS.	Mica heater elements, wound.
TOASTERS.	Mica heater elements, wound.
CAPACITORS.	Mica Plates.

Tubular eyelets can be fitted to Mica parts, or supplied separately.

All manufacturing processes including splitting, gauging, punching and checking, and inspection are carried out at Delanco Mica Division, at our Leonard Street E.C.2. factory.

Delanco MICA

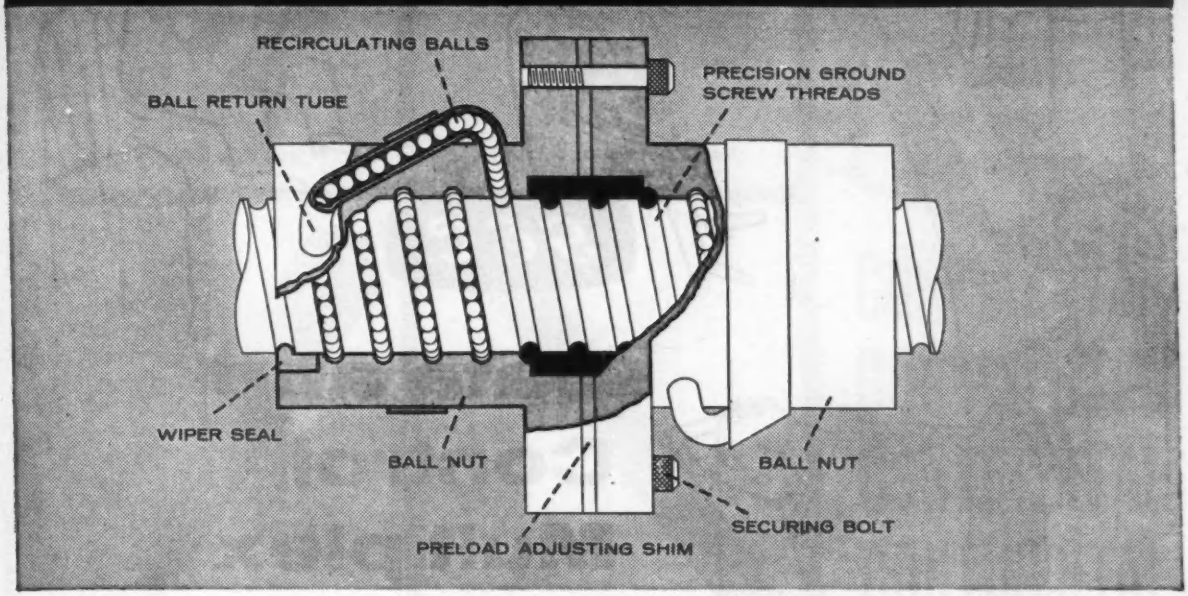
Anglo-American Vulcanized Fibre Co. Ltd

MICA DIVISION · CAYTON WORKS · BATH STREET · LONDON · E.C.1

Telephone: **CLE 3271** *Grams:* **PROMPSERV, AVE, LONDON**

DELANCO WORKS · LEONARD STREET · LONDON · E.C.2

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

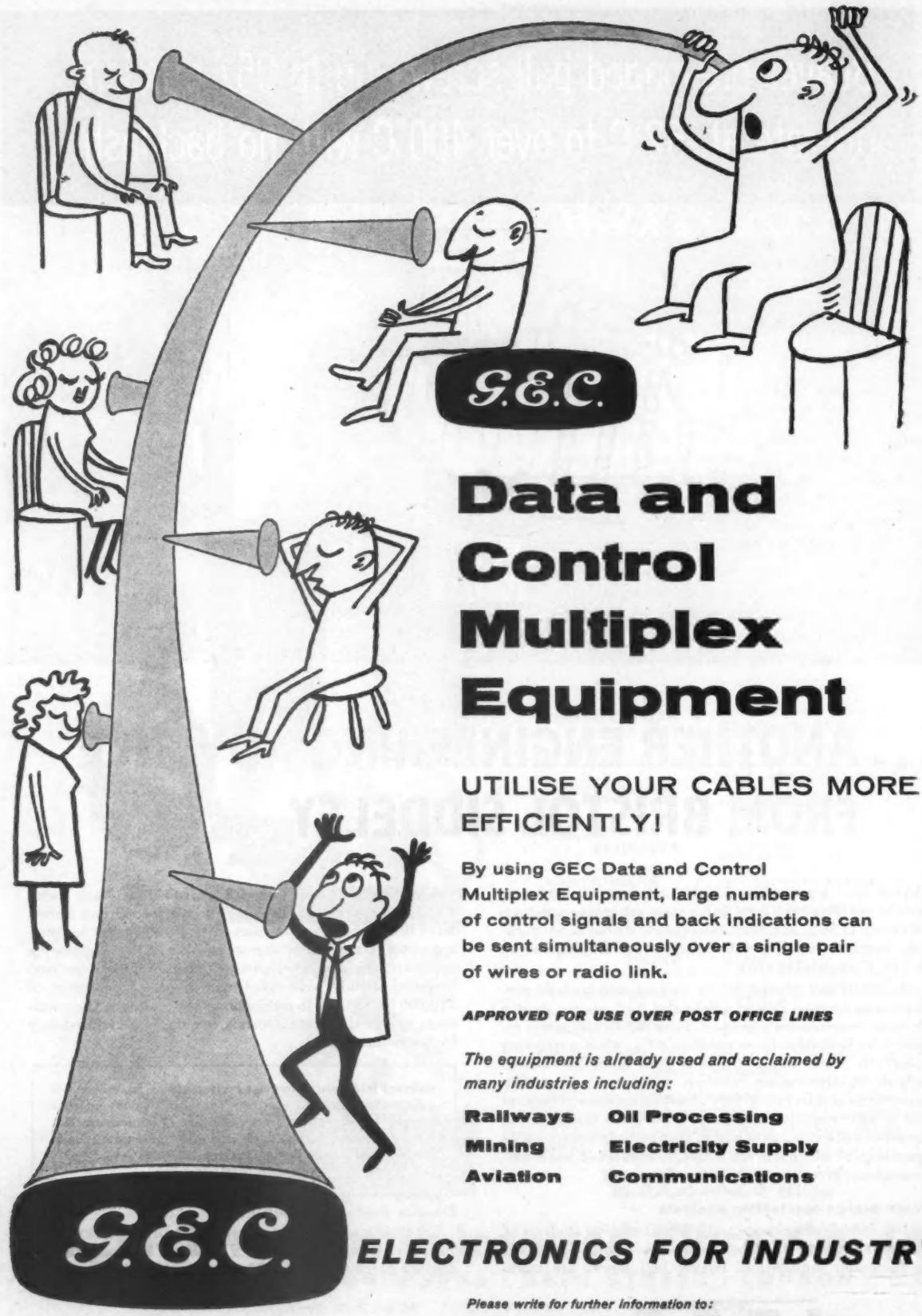
Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J. B. Starky, Sales Manager (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED



Data and Control Multiplex Equipment

UTILISE YOUR CABLES MORE EFFICIENTLY!

By using GEC Data and Control Multiplex Equipment, large numbers of control signals and back indications can be sent simultaneously over a single pair of wires or radio link.

APPROVED FOR USE OVER POST OFFICE LINES

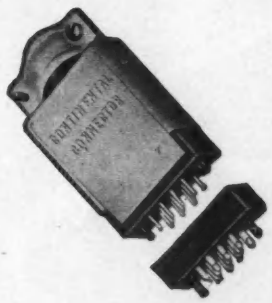
The equipment is already used and acclaimed by many industries including:

Railways	**Oil Processing**
Mining	**Electricity Supply**
Aviation	**Communications**

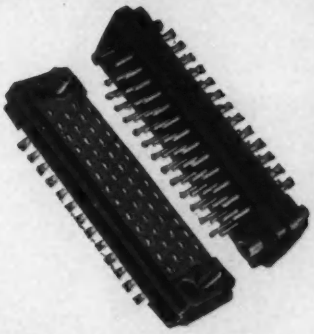
G.E.C. ELECTRONICS FOR INDUSTRY

Please write for further information to:
THE GENERAL ELECTRIC COMPANY LIMITED
Electronics Division · Ford Street · Coventry · England

Smee's G.E.C. 65

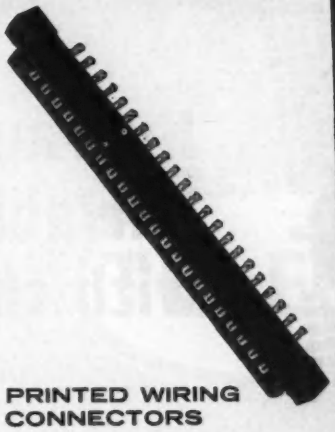


SUB-MINIATURE



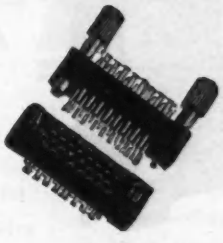
MINIATURE RANGE

TERMINAL BLOCKS



PRINTED WIRING CONNECTORS

SPECIALS



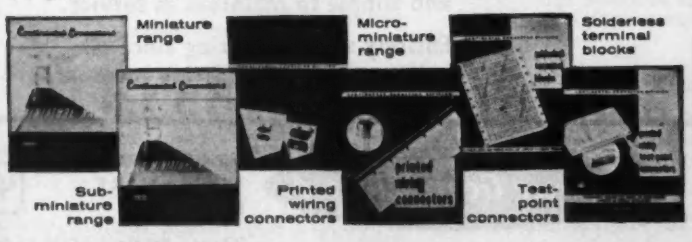
MICRO-MINIATURE

Are you interested in CONNECTORS?

Then this is the name to remember

CONTINENTAL
CONTINENTAL
CONTINENTAL
CONTINENTAL
CONTINENTAL
CONTINENTAL
CONTINENTAL
CONTINENTAL
CONTINENTAL

ASK FOR THESE BOOKLETS NOW



WRITE TO

CONTINENTAL CONNECTORS LTD
Industrial Estate, Long Drive
Greenford, Middlesex
Tel: WAXlow 5721-7

(associated with the Ultra Group of Companies)

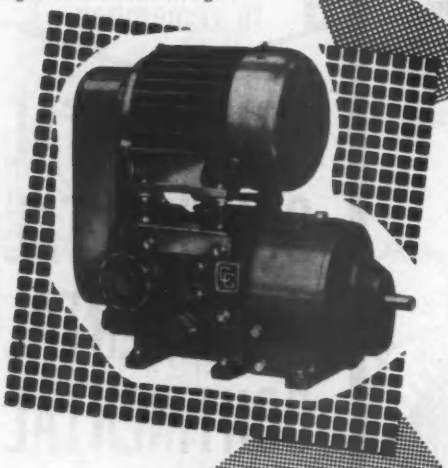
Continental Connectors

HCN 100

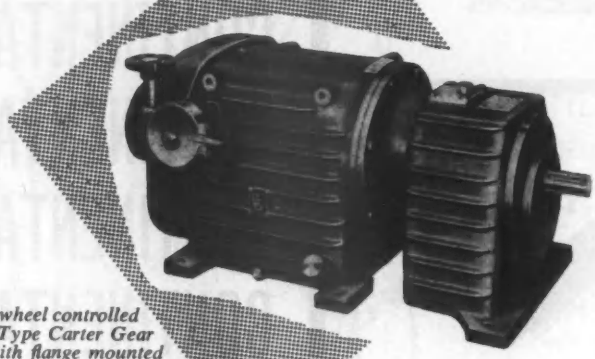
Fractional horsepower 'F' Type Carter Gear, Handwheel Speed Control

'A' Type Carter Gear, push button operated Remote Electrical Control

'F' Type Carter Gear, top mounted motor and flange mounted reduction gear



Hydraulic Variable Speed Drives with these advantages



Handwheel controlled 'A' Type Carter Gear with flange mounted reduction gear

Wide infinitely variable speed range (approximately 27/1 on full load).

Sensitive accurate speed control by Hand, Electrical or Lever arrangements.

Constant output torque throughout the entire variable speed range.

Positive displacement action ensures maximum 'controllability' at all speeds.

Carter Variable Speed Gears may used to pick up loads from zero r.p.m.

Controls may be operated with the drive either running or stationary.

Made in ten sizes for fractional up to forty horsepower drives.

Flange mounted reduction gears can be supplied for slow speed drives.

Compact, efficient, easy to install and simple to maintain in service.

Entirely self-lubricating since oil is the power transmitting medium.

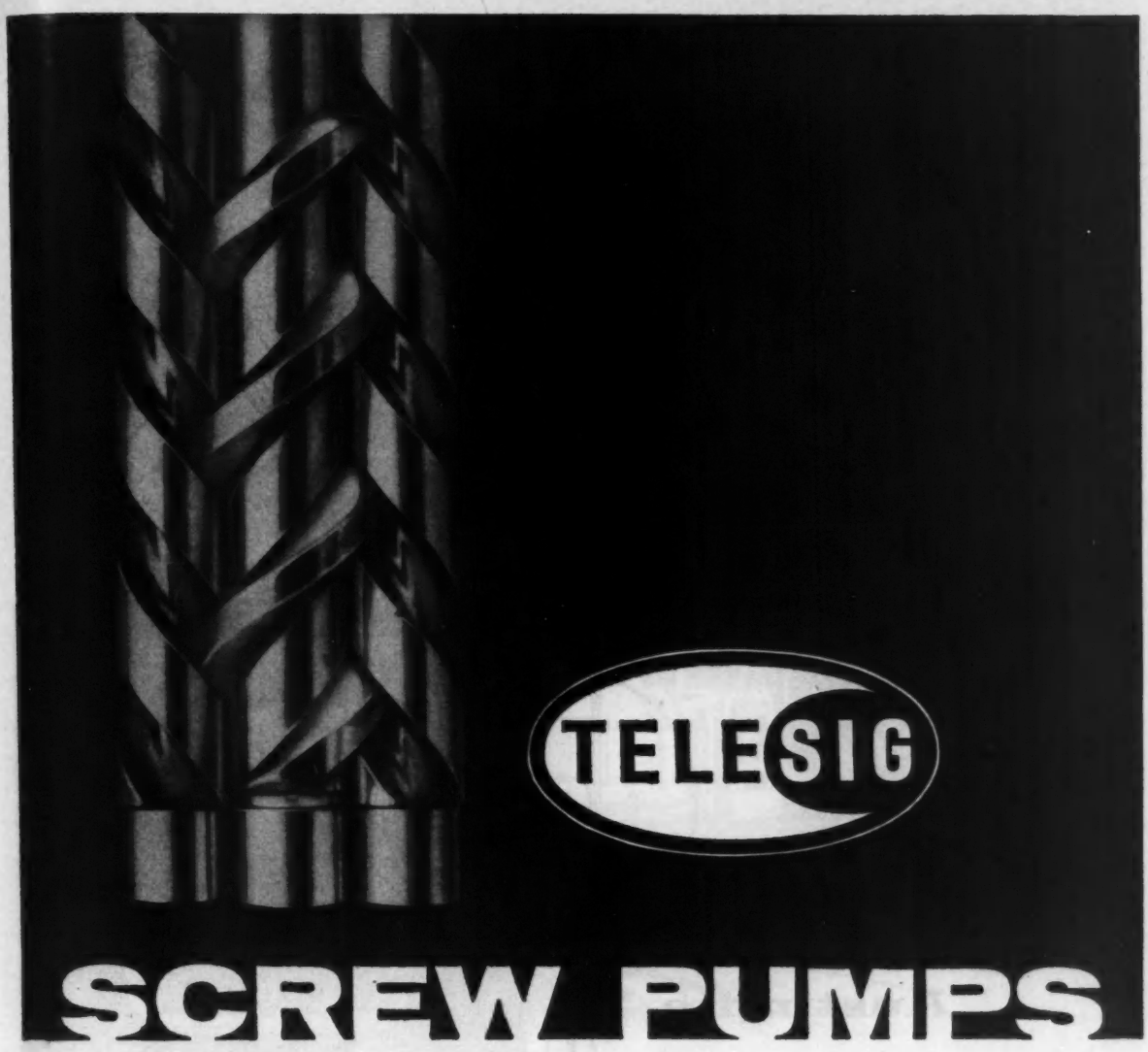
Specialists for over 20 years in the design, manufacture and industrial application of Hydraulic Variable Speed Gears.

write for Folder 1660

Carter Gears Limited

BRADFORD 3
YORKSHIRE
ENGLAND

'phone Bradford 64378 (3 lines)
'grams 'Became' Bradford Telex.



TELESIG Screw Pumps are positive displacement pumps. Simply constructed, they offer exceptional performance and long life. TELESIG pumps effect delivery by means of three parallel screws engaging each other, the power-driven central screw driving the two side screws. They may be run at high speed thereby reducing motor sizes and installation costs.

TELESIG Screw Pumps offer the following advantages:

- Self priming.
- Delivery free from pressure pulsation.
- High working speed — small size.
- Near-silent operation.
- Simple construction.
- Minimum maintenance and easy replacement of working parts.
- Long life.

TELESIG Screw Pumps are made in three basic ranges: for low pressures up to 300 psi, for medium pressure up to 1000 psi and for high pressures up to 2,500 psi. 42 sizes are available covering a wide range of capacities.

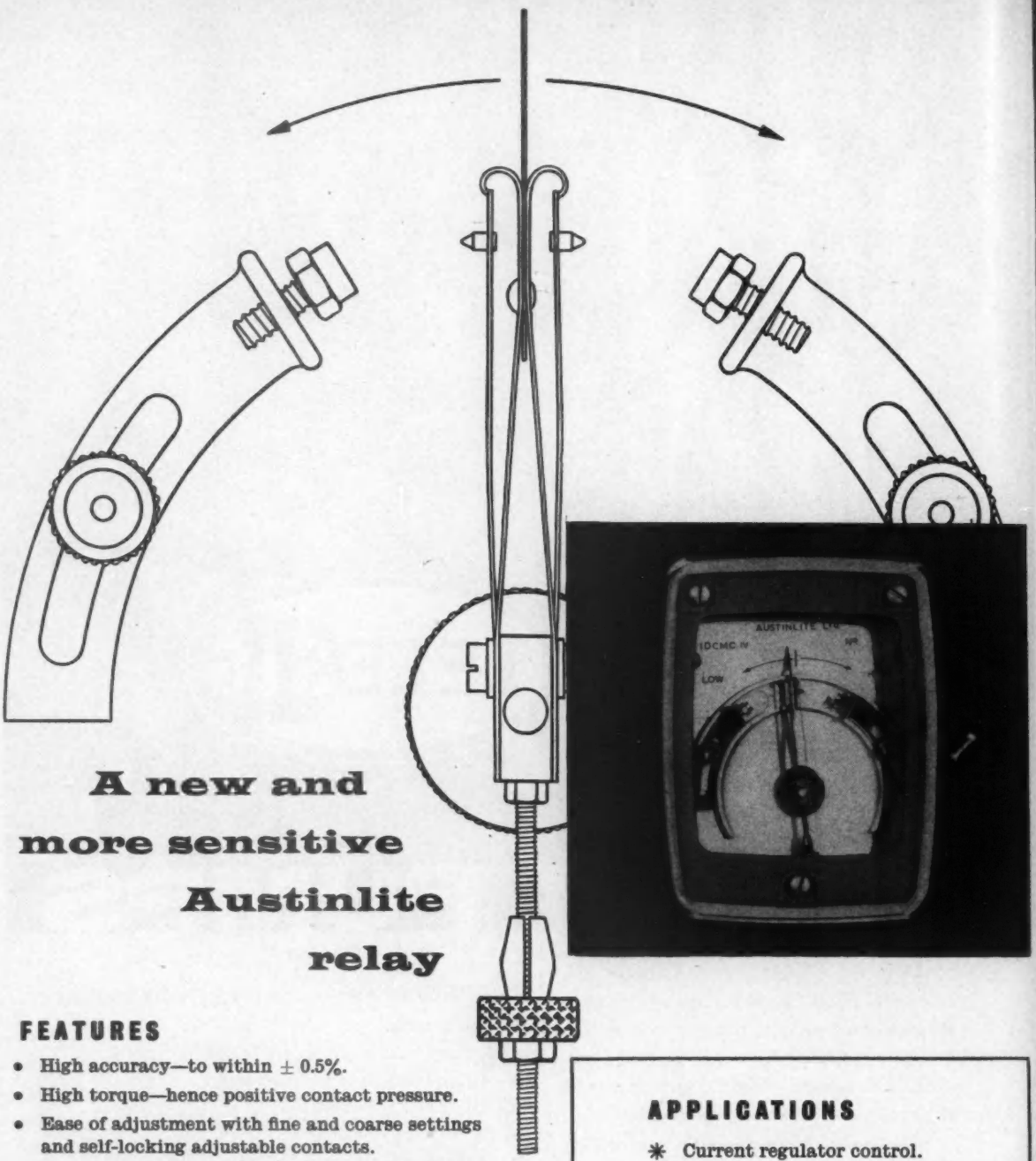
TELESIG

Screw Pumps by Telehoist

TELESIG pumps and equipment are made by Telehoist under licence from the Swiss Industrial Company (SIG).

Telehoist Limited. Cheltenham England. Telephone: Cheltenham 53254

an associate company of Wilmot Breeden Ltd.



A new and more sensitive Austinlite relay

FEATURES

- High accuracy—to within ± 0.5%.
- High torque—hence positive contact pressure.
- Ease of adjustment with fine and coarse settings and self-locking adjustable contacts.
- Choice of either two or four adjustable contacts.
- Contemporary case design—projection or flush mounting.
- Dustproof and suitable for use in the tropics.
- Conforms to Post Office Specification P.T. 1025B.
- Suitable for current or voltage sensing on either D.C. or A.C.

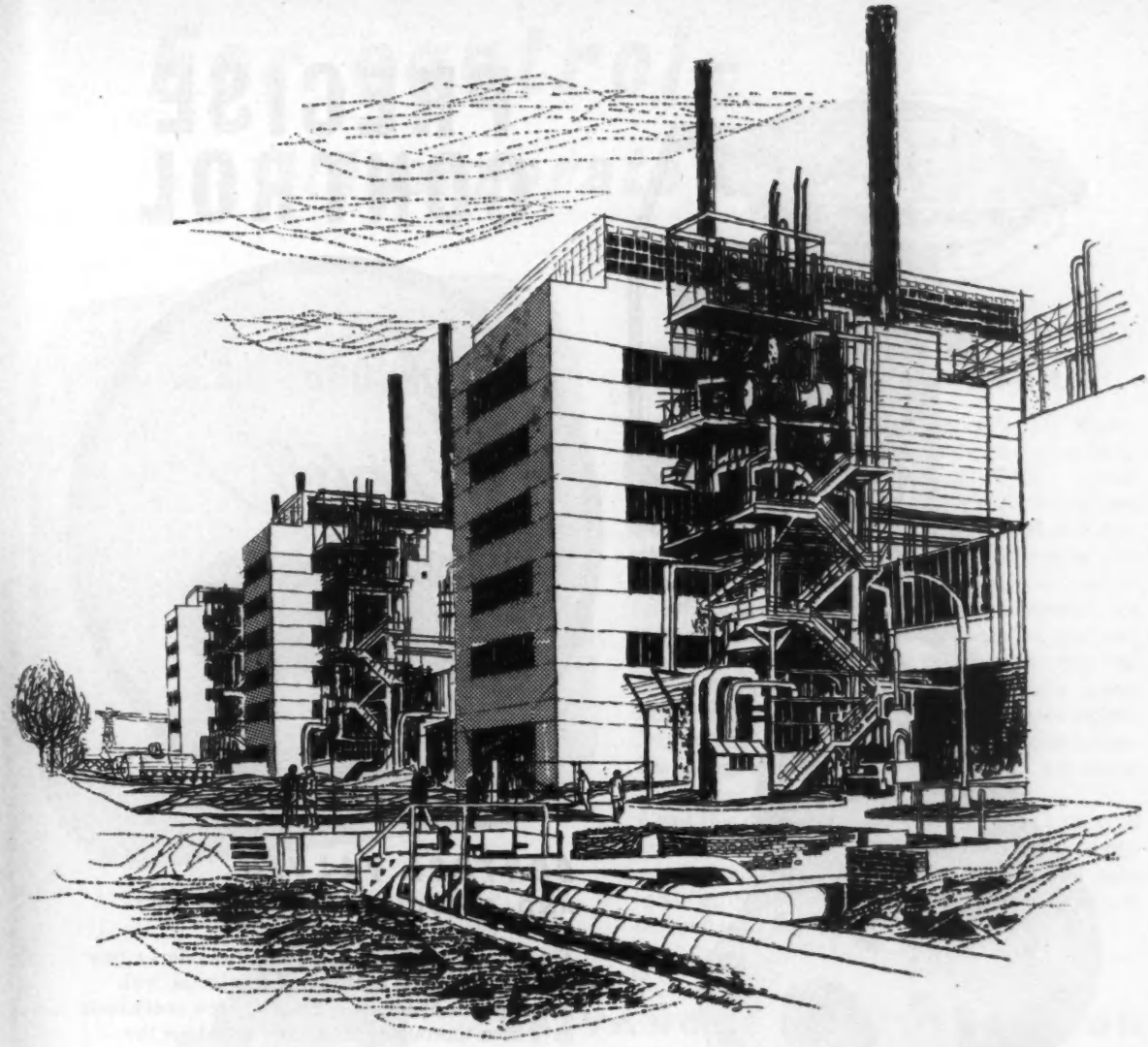
APPLICATIONS

- ✳ Current regulator control.
- ✳ Voltage regulator control.
- ✳ Monitoring duties.
- ✳ Limiting duties.
- ✳ Equipment protection.

Austinlite **ELECTRICAL EQUIPMENT**

Custom-built by STONE-CHANCE LTD.

(Makers of Sumo Pumps and Stone-Chance Lighthouses).
CRAWLEY, SUSSEX.



the applications of Ermeto high pressure couplings are practically unlimited

Ermeto high pressure couplings are specified by many leading manufacturers because of their proven reliability under arduous conditions. They are available in mild and stainless steel, brass and aluminium alloy. Couplings, valves and flexible hose are supplied in a wide range of standard fittings. Non-standard fittings can also be made to meet your specifications. Technical information and our illustrated catalogue are freely available on request.

ERMETO

BRITISH ERMETO CORPORATION LTD

HARGRAVE ROAD · MAIDENHEAD · BERKS · TELEPHONE: MAIDENHEAD 5100

A member of the ALENCO Group of Companies

Circle **No 54** on reply card for further details

PRECISE CONTROL

COCKBURNS B.S.B.

Super 70

CONTROL VALVES
AND ASSOCIATED EQUIPMENT

The Cockburns B.S.B. Super 70 series offers a new standard in precise control and regulation, with pneumatic or hydraulic operation. Flow coefficients have been thoroughly laboratory tested for the complete range of valves. Super 70 valves have demonstrated their superior performance characteristics in oil refineries, chemical plants and power stations all over the world.

Cockburns Ltd., and their Associated Companies in the United Kingdom, Holland and France are now manufacturing Super 70 series Control Valves, Regulators, Liquid Level Controllers, under licence from Black, Sivalls, & Bryson, Kansas City, U.S.A.

NOW being manufactured in Europe

Black, Sivalls & Bryson, inc.

– COCKBURNS LTD

COCKBURNS LTD.
Cardonald, Glasgow, S.W.1.

COCKBURNS (NEDERLAND) N.V.
Kethel, Schiedam.

For control–
incorporate

D.C. MICROAMMETERS

A range of sensitive, robust and accurate D.C. Microammeters, such as those which in the past years have been incorporated in the famous "EEL" photo-electric instruments, is now available to the instrument user. They are extremely favourably priced and realistic delivery dates can be offered. Moreover, the Company will be pleased to co-operate with other manufacturers contemplating the incorporation of microammeters. Two ranges are available, the first, Type "S", being from 7 up to 500 microamps full scale deflection. The low coil resistance value makes them ideally suited for incorporation in photo-electric circuits where high resistance could affect linearity. The second range is available from 10 to 500 microamps, these having higher coil resistance.
Whilst this does offer the user a wide choice of units, the Company are also prepared to manufacture other values if required. The units are available with right-hand, left-hand or displaced zero scale markings as required by the customer.

GALVANOMETER SUSPENSION
TYPE A

A Galvanometer of unique design possessing excellent stability and zero-keeping qualities.

Completely sealed against dust, thus eliminating coil stiction and loss of linearity.

Clamping device holds coil rigid and relieves ligament tension, providing a very robust unit.

Widely used in test gear, bridge and potentiometric devices.

Available in eight different coil resistance values, or to customer's specification.

EVANS ELECTROSELENIUM LTD

SALES DIVISION 95 ST. ANDREW'S WORKS, HALSTEAD, ESSEX

SALES AND SERVICING AGENTS THROUGHOUT THE WORLD

on-off-
on-off-
on-off-

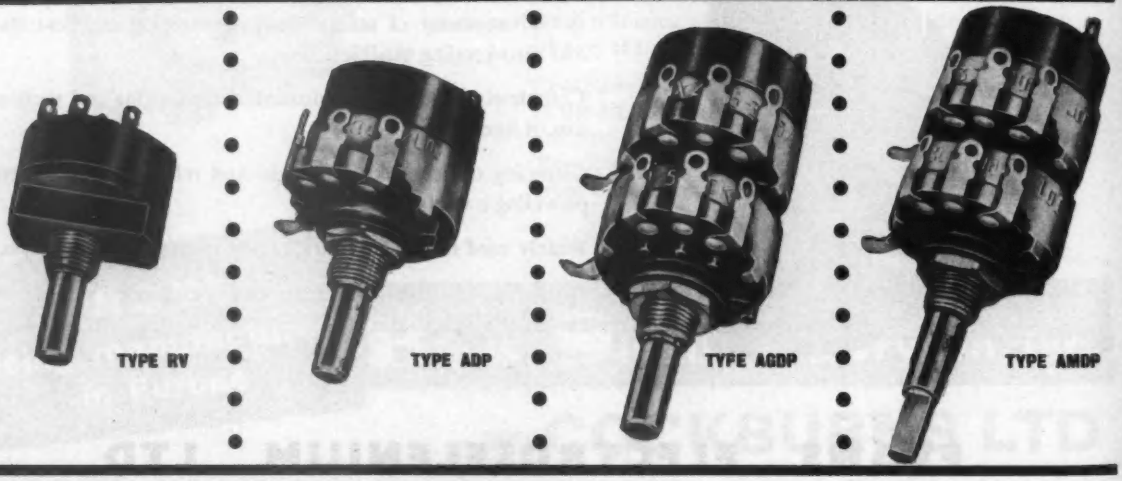
20,000 times!

Whether you export your radio, television or audio equipments to Scandinavia or not, SEMKO approval of components is important to you for its own sake. It guarantees a quite exceptional reliability and safety.

The Morganite Type 'V' switch is rated at 250 volts **2 amperes** and is therefore one of the highest rated SEMKO approved potentiometer switches of wholly British manufacture.

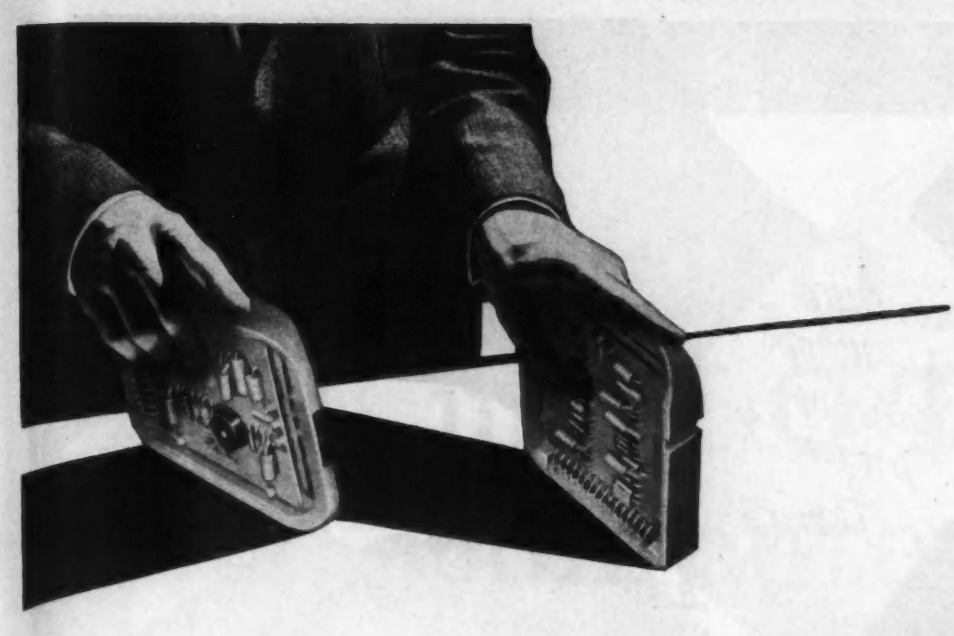
The SEMKO series of tests includes 20,000 operations at full load without a single permissible (even momentary!) mechanical or electrical failure. Compare that with the average 2,000 operations per year that a switch gets in actual use, and you see what the famous 'S' symbol on a Morganite switch means in terms of service! Fully complies with BSS415 too.

SEMKO approval for Morganite Potentiometer Switches



MORGANITE RESISTORS LTD.
BEDE TRADING ESTATE · JARROW · COUNTY DURHAM
TELEPHONE: JARROW 89-7771

J100A/344



DO YOU KNOW

... **that** 'Datapacs' are a range of transistorised logical elements from which control systems can be built up for all forms of

Telemetry
Data Handling and
Data Logging

... **that** these systems can be extended or modified to meet requirements

... **that** easy maintenance, minimum equipment and reliability are inherent features provided by these units

'ENGLISH ELECTRIC'

data processing

The ENGLISH ELECTRIC Company Ltd.,
English Electric House, Strand, London, W.C.2

Data Processing and Control Systems Division,
Kidsgrove, Stoke-on-Trent, Staffs.
Telephone: Kidsgrove 2141/3

EDC. 27

Circle No 58 on reply card for further details

off the cuff . . .

The New BURGESS V-4

* No larger than the average cuff-link
* New mechanism has mechanical life of at least 10 million operations
* Three types of solder terminals available
* Comprehensive range of auxiliary actuators

BURGESS MICRO SWITCHES

BURGESS PRODUCTS COMPANY LTD, MICRO SWITCH DIVISION, DUKES WAY, TEAM VALLEY, GATESHEAD 11
Telephone: Low Fell 75322. Telex: 53-229 London Office: 127 Victoria Street, SW1. Telephone: TATe Gallery 0251 Telex: 2560

G.P.O use I·C·T computer

TIME OF STORES PROVISIONING CUT BY TWO-THIRDS

Without the efficiency of their stores provisioning, G.P.O. telecommunications could never be the extremely competent public service that they are today. Every one of the 30,000 items stocked should be available immediately throughout the vast countrywide network; yet, to avoid locking up too much capital, no item must be overstocked.

This is one of the world's most formidable stock control jobs. With their advanced thinking it was natural that the G.P.O. should turn to electronics to increase their efficiency. They chose for immediate use an I·C·T 1200 series computer. This computer has been working for a year only, but it has already demonstrated its value as a tool for controlling a stockholding worth £48 million.

It accurately reviews thirty thousand items each month; indicates unbalance, excesses and shortages, and consistently assists in maintaining the stores holding at the practical minimum. In fact, as Mr. Bevins, the Postmaster General, said recently: 'This computer has allowed us to cut by two-thirds the time taken to obtain the key facts we need to keep our stock of 30,000 different items of engineering stores adequately, but not more than adequately, replenished.'

An I·C·T computer can help your business, too

It can make *your* wires hum faster by directly assisting your management and financial accounting, production control, or whatever your particular problem may be. A computer is certainly a major investment; but the dividend it pays is enormous.

I·C·T

INTERNATIONAL COMPUTERS AND TABULATORS LIMITED

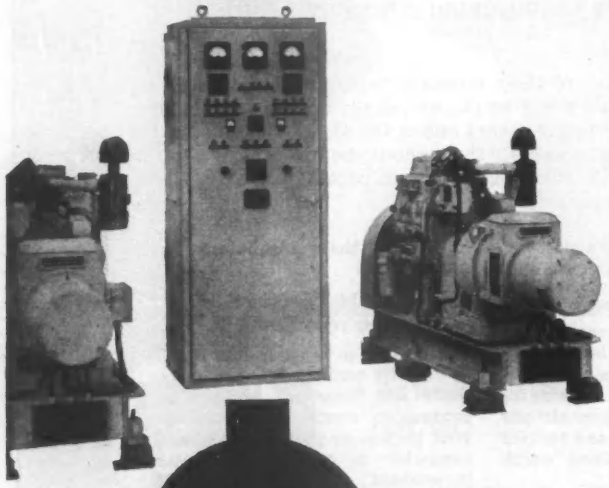
for Britain's most widely used commercial computers

149 Park Lane, London W1

PELAPONE

A VITAL LINK IN TELECOMMUNICATIONS

Automatic Power Plants for Repeater Stations



Pelapone Dual or Triple Automatic Stand-by plants, designed for continuous service without supervision, are to be found wherever an uninterrupted power supply is essential.

Dependable Pelapone generating sets, operating alternately as 'duty' and 'stand-by', and automatically controlled may be left unattended with complete confidence—periodic visits only being necessary for fuel replenishment and normal maintenance. Absolutely reliable under adverse conditions in all climates, they form the *vital link* in national and international communications networks. For dependability and minimum "outage" time—specify Pelapone.

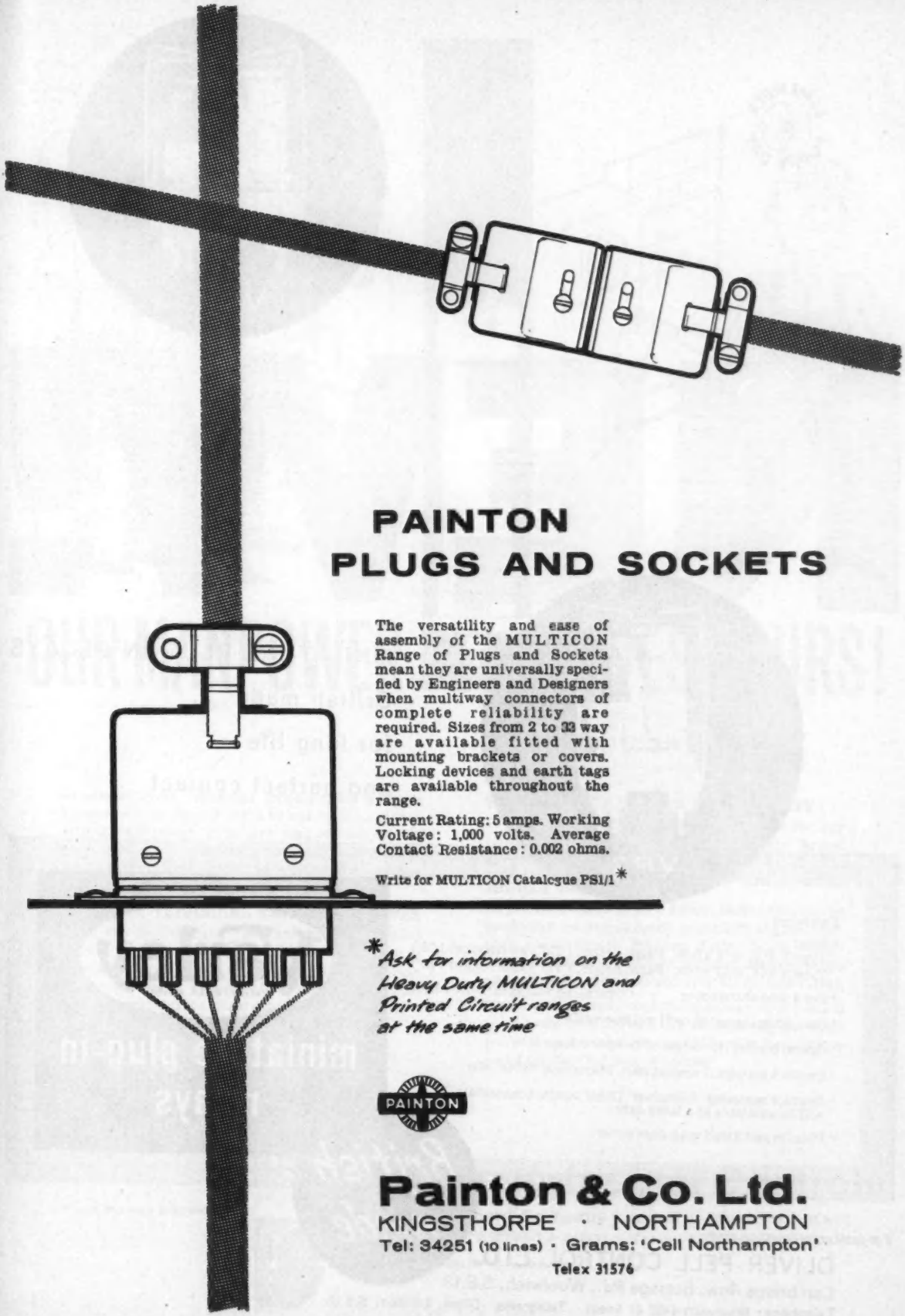
662

PELAPONE LIMITED

SALES DIVISION: 38/40 BRUTON STREET, LONDON, W.1.

WORKS: P.O. BOX 4, DERBY.

CONTROLLED POWER - CONTINUOUS POWER



PAINTON
PLUGS AND SOCKETS

The versatility and ease of assembly of the MULTICON Range of Plugs and Sockets mean they are universally specified by Engineers and Designers when multiway connectors of complete reliability are required. Sizes from 2 to 33 way are available fitted with mounting brackets or covers. Locking devices and earth tags are available throughout the range.

Current Rating: 5 amps. Working Voltage: 1,000 volts. Average Contact Resistance: 0.002 ohms.

Write for MULTICON Catalogue PS1/1*

Ask for information on the Heavy Duty MULTICON and Printed Circuit ranges at the same time

PAINTON

Painton & Co. Ltd.

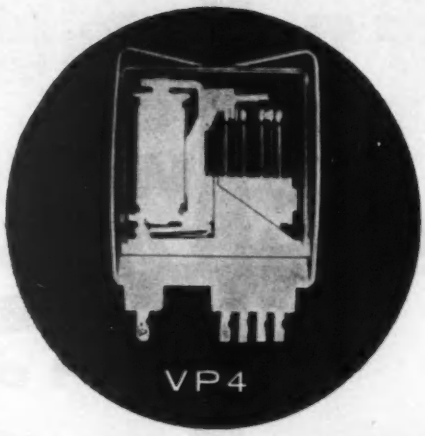
KINGSTHORPE · NORTHAMPTON

Tel: 34251 (10 lines) · Grams: 'Cell Northampton'

Telex 31576

Circle No 62 on reply card for further details

REMEMBER POPPY DAY



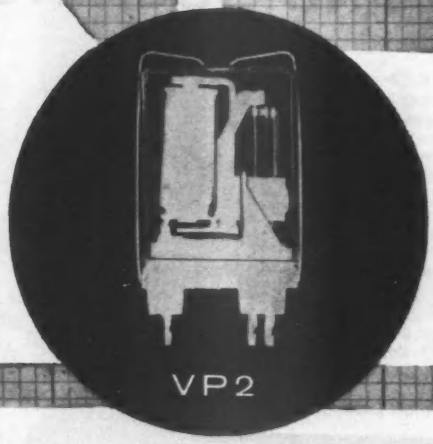
NEW!

MINIATURE PLUG-IN RELAYS

British made . . .

for long life

and perfect contact



Features:

* Size:
  Type V.P.2. 0·75″x0·96″ Panel height 1·175″ (with socket 1·35″)
  Type V.P.4. 0·75″x1·18″ Panel height 1·175″ (with socket 1·35″)
* 2 or 4 pole changeover
* Operating voltages: 6–138v D.C.
* Operating times: 3½ to 7½ milleseconds
* Operating life: in excess of 10^7 operations
* Contact ratings: 1 amp at 100v. Maximum watts: 30w
* Contact material: fine silver. Other contact materials will be available at a later date
* Plug-in and fitted with dust cover.

Varley
REGD. TRADE MARK

miniature plug-in relays

British made

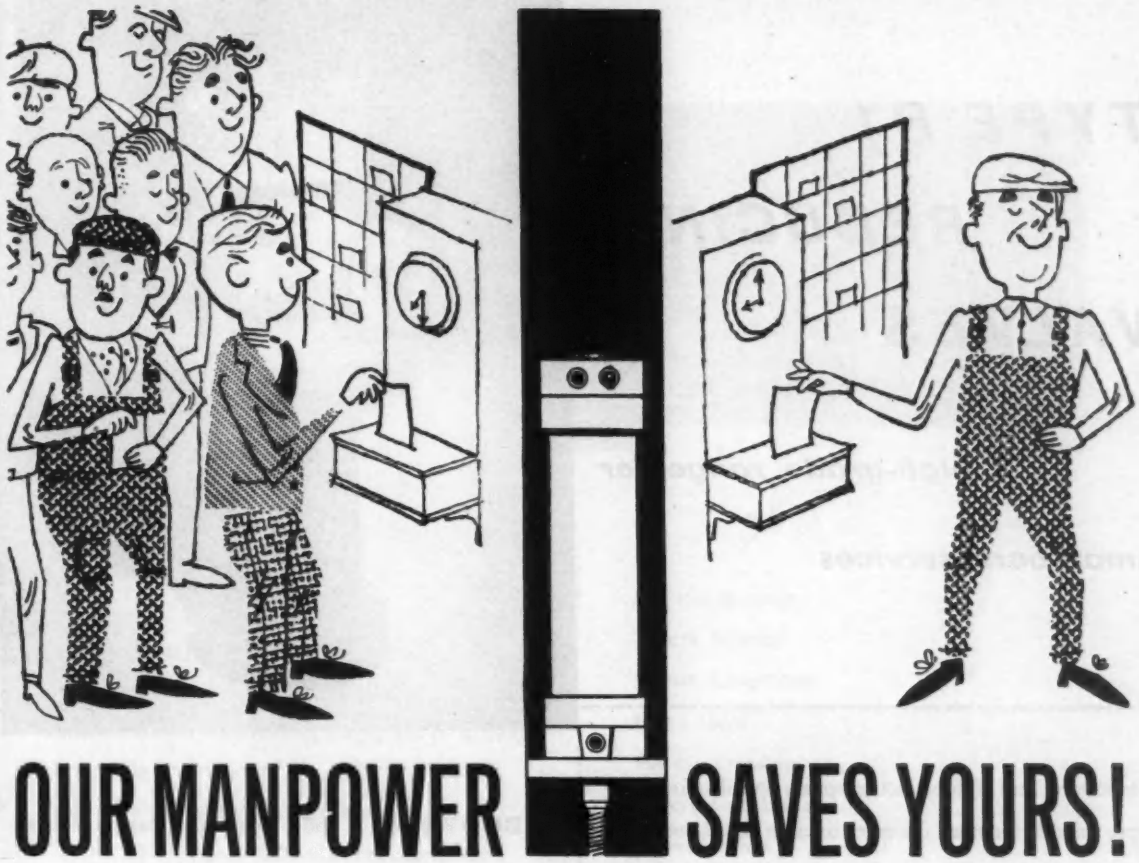
For further information write:—

OLIVER PELL CONTROL LTD.

Cambridge Row, Burrage Rd., Woolwich, S.E.18

Telephone: Woolwich 1422 (7 lines) Telegrams: Olipel, London, S.E.18

TA 4220



OUR MANPOWER SAVES YOURS!

In almost every industrial process there is some stage where manpower could be cut by the application of fluid power. It is here that our labour can prove so labour-saving, since the whole weight of the Baldwin Fluid Power Division is directed at cutting waste manpower and speeding production.

BALDWIN TECHNICAL REPRESENTATIVES cover the British Isles. They are experienced fluid power engineers, who will quickly show you how to harness waste or under-used power by fitting Baldwin equipment which, because of its unit construction, can be supplied from stock quickly.

Write now for the Fluid Power Catalogue C/503

THE EXPERT BALDWIN DESIGN STAFF at Dartford will plan automation schemes for any operation or series of operations up to the largest automatic production lines.

HIGHLY SKILLED MEN on the Baldwin shop floor devote their attention to producing the superb finish, reliability and precision that characterises Baldwin Fluid Power equipment. There is a standard range of 384 pneumatic and hydraulic cylinders and over 700 control valves.

We have long found that the best way to success is to give the best service. At every level, our manpower is aimed at increasing production for industry —and for Baldwin too, of course!

Fluid Power Division

Baldwin Industrial Controls

Baldwin Instrument Company Limited · Dartford · Kent

Telephone Dartford 20948 & 26411 · Cables & Telex Baldwin Dartford

A HARPER GROUP COMPANY

B/33

Circle No 64 on reply card for further details

TYPE R1 REDUCING VALVES

A high-grade range for small-bore services

These valves are of direct-acting spring-and-diaphragm type, suitable for small diameter lines on liquid, steam, air, or gas service. Though of simple, robust character, they are much more fully considered in design, construction, and range of application than is usual in valves of this class.

Accurately known characteristics, plus a wide choice of interchangeable control springs and trim types and sizes, ensure correct matching to conditions and predictable quality of control. Once adjusted for service, these valves will give dependable operation over long periods without further attention.

BODY $\frac{3}{8}$", $\frac{1}{2}$", $\frac{3}{4}$" and 1". Cast iron, bronze or steel.

TRIM Metal-to-metal (flat or needle stopper), or fluon soft-faced (renewable).

DIAPHRAGM Neoprene (nylon re-inforced), or metal.

MAX. INLET PRESSURE Up to 1200 psig., according to material, service temperature, and trim size.

MAX. REDUCTION RATIO Up to 500 to 1, according to flow capacity required.

MIN. REDUCTION RATIO 1·2 to 1.

MAX. TEMPERATURE Up to 600°F., according to materials.

For full specification and performance data, see Publication No. 228B, free on request.

BLAKEBOROUGH

J. BLAKEBOROUGH & SONS LTD · BRIGHOUSE · ENGLAND

Printed Circuit Counter Panels

A complete range of transistorized counter panels of common size, fixing method and electrical connexion, designed to provide a flexible unit system whereby any special requirements in the counting or data processing fields can be quickly built up.

A fully illustrated brochure giving complete performance and specification figures for every panel in the range is available on request.

50kc/s Scaler
1Mc/s Scaler
Input Amplifier
Gate Unit
10kc/s Oscillator
1Mc/s Oscillator
Power Unit
50kc/s Read-out Scaler
1Mc/s Read-out Scaler
4 Channel Output Unit
Read-out Unit
Meter Display Unit
Lamp Display Unit
Numerical Indicator Tube
Shift Register Stage
Shift Register Driver

CINTEL INSTRUMENT Division

RANK CINTEL LIMITED
Worsley Bridge Road · London · SE 26
HIther Green 4600

Sales and Servicing Agents: Atkins, Robertson & Whiteford Ltd. Industrial Estate, Thornliebank, Glasgow; McKellen Automation Ltd., 122 Seymour Grove, Old Trafford, Manchester, 16; Hawnt & Co. Ltd. 112/114 Pritchett Street, Birmingham 6

the STANTEC computing system

incorporating a transistorized electronic digital computer

This system, which employs the programming philosophy of the Stantec-Zebra Computer, has these facilities:

1 Fast Multiplication
2 Increase of available I.A.S. and main store location
3 High-speed paper tape input/output
4 Magnetic tape input and output and as backing store
5 Punch card input/output

A complete medium size data processing system of extreme flexibility at reasonable outlay.

STC is Britain's biggest exporter of digital computers

ELECTRONIC SYSTEMS GROUP

60/6L

Standard Telephones and Cables Limited

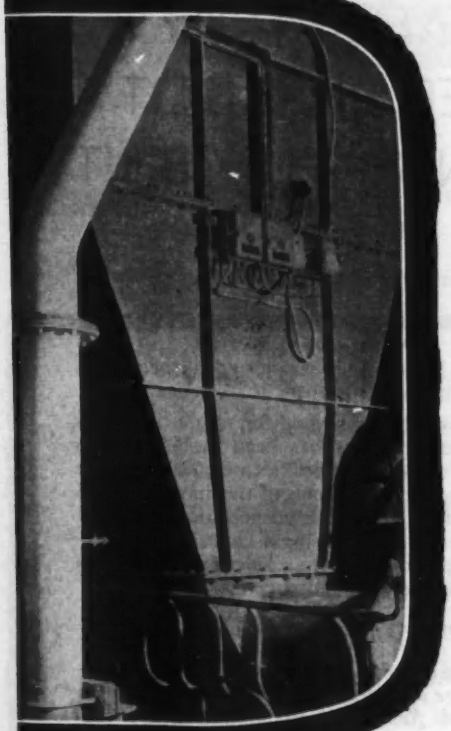
Registered Office: Connaught House, Aldwych, London, W.C.2

INFORMATION PROCESSING DIVISION: CORPORATION ROAD · NEWPORT · MON.

Circle No 67 on reply card for further details

st in Level Control

with the now famous capacitance method



The principle of electrical capacity is employed to detect the approach of any substance to (or recession from) the probe. The consequent change in capacitance is made to actuate a relay in the Fielden Tektor which can switch in an audible or visible alarm for high level and/or low level control of liquids or solids. Alternatively, it can control in a container the material at a predetermined level.

Since operation does not rely on contact with the substance the probe can be covered with anti-corrosive and heat-resistant insulation if required.

Easily installed and simply maintained.

No moving parts in or on the container.

Electronic unit can be up to 150 feet from the container.

Multiple Tektor units can be supplied in one control panel for centralised level control where a number of control points exist, thus saving considerably in installation costs.

Simplicity of design and printed circuits ensure exceptional reliability. A wide range of probes for use with all materials — ranging from fine powders to run-of-the-mine coal, acids to bases, conductors to insulators — at varying temperatures and pressures.

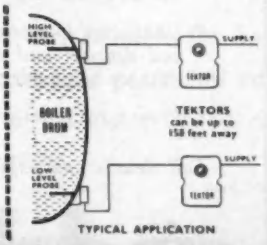
12

years experience

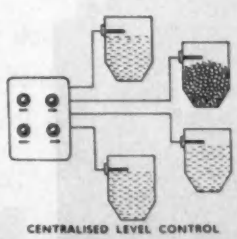
is behind every Fielden level controller and indicator — backed by first grade Application, Commissioning and Servicing Facilities.

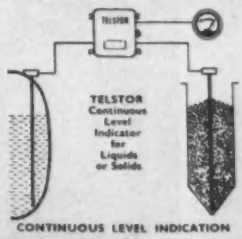
Over 100,000 Tektors and Telstors in operation throughout the world.

Illustration above shows a hopper at G. & T. Earle Ltd., Fielden high and low level Tektors are fitted to provide efficient packaging of cement by preventing overflow or running empty.



TYPICAL APPLICATION


CENTRALISED LEVEL CONTROL



CONTINUOUS LEVEL INDICATION

Fielden

WRITE FOR LEAFLET GL1/C

FIELDEN ELECTRONICS LTD · WYTHENSHAWE · MANCHESTER Phone: Wythenshawe 3251 (4 lines) Grams: Humidity Manchester

ALSO AUSTRALIA, ITALY AND CANADA *Branch Offices:* LONDON, WALSALL, STOCKTON-ON-TEES, EDINBURGH (A. R. BOLTON LTD). AND DUBLIN.

Agents throughout the world

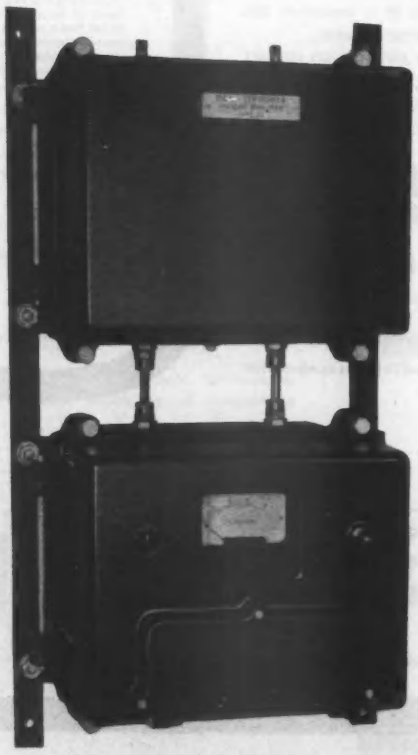
Indicating Recording Control

TT4

Circle **No 68** on reply card for further details

a new approach to oxygen analyser design

GIVES FASTER RESPONSE, SAFER AND EASIER OPERATION, GREATER RELIABILITY AND ACCURACY, WIDE RANGE—FLEXIBILITY EXTREME RUGGEDNESS—



An all-British analyser designed specifically for arduous chemical plant service.

Faraday's direct method for measuring magnetic susceptibility has been modernised to give a rapid and specific measurement free from the technical snags of the magnetic wind principle. The delicate suspension is replaced by rare metal, providing a virtually unbreakable measuring system. The analyser is ideal for boiler control and chemical process use.

* *F.S.D. 1% to 100% in six ranges*
* *Rapid response—95% response to input step-change achieved in 8 seconds with maximum sample flow-rate*
* *Metal dumb-bell suspension proved against shocks of 2,000 g*
* *Unaffected by viscosity, thermal conductivity and density, and insensitive to tilting and changes in sample flow rate*
* *Proved by years of plant use*

Full details and expert technical advice from

SERVOMEX CONTROLS LIMITED
(Chemical Instruments Division)
CROWBOROUGH SUSSEX
Telephone Crowborough 1247

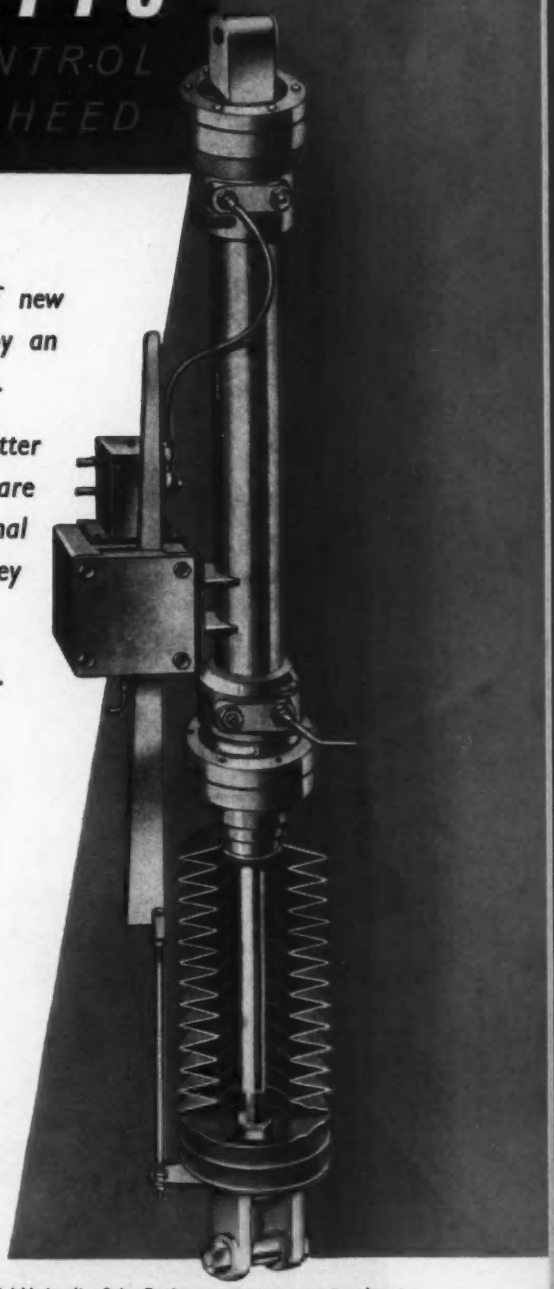
DCL SERVOMEX **Oxygen Analyser type 83**

Circle No 70 on reply card for further details

NEW

HYDRAULIC PNEUMATIC

POSITIONAL-CONTROL UNITS BY LOCKHEED



WE are now able to supply a range of new hydraulic cylinders positionally controlled by an air signal with a pressure range of 3-15 p.s.i.

The cylinders have a positional accuracy of better than ·5% of the total cylinder stroke and are free from overshoot when dealing with frictional loads or even high dynamic loads, provided they are operating at a relatively low frequency.

The range at present covers efforts up to 3,000 lbs. at 1,000 lbs. p.s.i.

Automatic locking of cylinders on air or hydraulic failure can be provided, together with overriding manual positional control.

This equipment is very suitable for boiler damper controls, boiler water feed positional valve control, boiler water feed pump/motor speed control and many other applications.

Regd. Trade Mark

Lockheed

INDUSTRIAL HYDRAULICS

LOCKHEED PRECISION PRODUCTS LIMITED

INDUSTRIAL HYDRAULICS DIVISION

SHAW ROAD, SPEKE, LIVERPOOL 24 Telephone: Hunts Cross 2121 Telex 62394

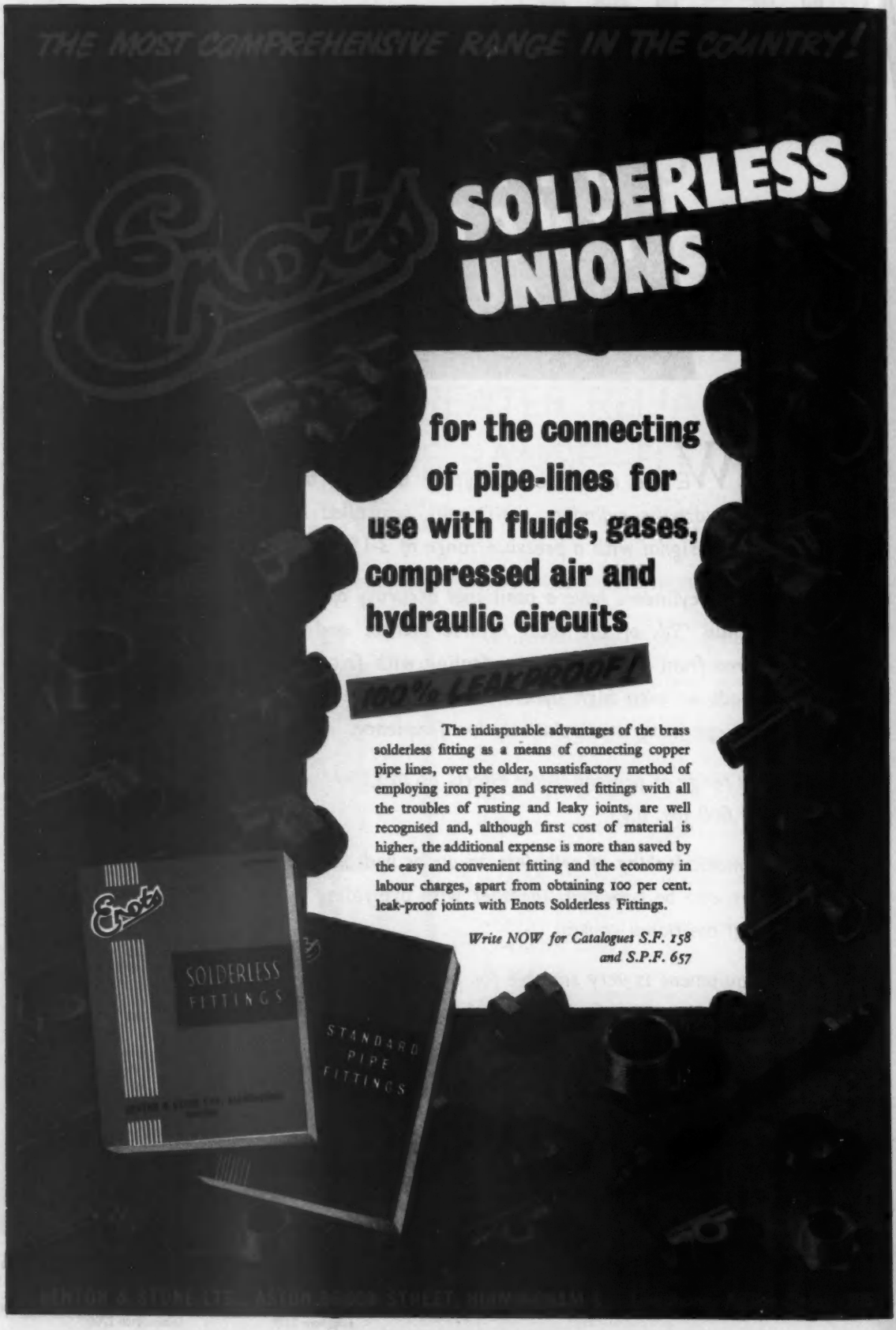
ONE OF THE AUTOMOTIVE PRODUCTS GROUP

Industrial Hydraulics Sales Engineers are at your service also at

Automotive House, Great Portland Street, London, W.1 Langham 2527

Tachbrook Road, Leamington Spa, Warwickshire Leamington 2700

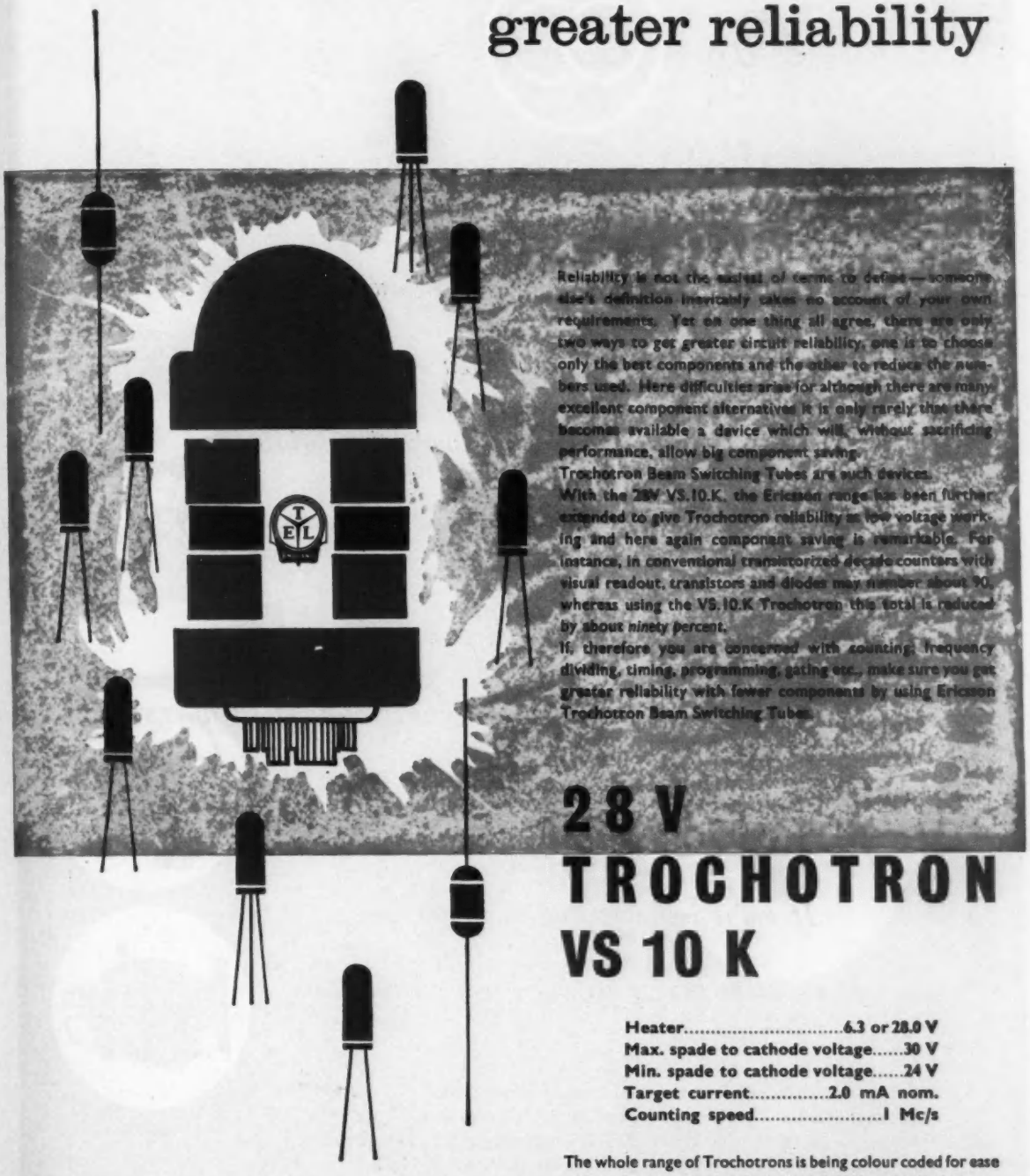
144 St. Vincent Street, Glasgow, C.2 Central 0291


THE MOST COMPREHENSIVE RANGE IN THE COUNTRY!
Enots
SOLDERLESS UNIONS
for the connecting of pipe-lines for use with fluids, gases, compressed air and hydraulic circuits
100% LEAKPROOF!
The indisputable advantages of the brass solderless fitting as a means of connecting copper pipe lines, over the older, unsatisfactory method of employing iron pipes and screwed fittings with all the troubles of rusting and leaky joints, are well recognised and, although first cost of material is higher, the additional expense is more than saved by the easy and convenient fitting and the economy in labour charges, apart from obtaining 100 per cent. leak-proof joints with Enots Solderless Fittings.
Write NOW for Catalogues S.F. 158 and S.P.F. 657
Enots
SOLDERLESS FITTINGS
STANDARD PIPE FITTINGS

See Enots list of stockists on page 190

Fewer components . . .

greater reliability



Reliability is not the easiest of terms to define — someone else's definition inevitably takes no account of your own requirements. Yet on one thing all agree, there are only two ways to get greater circuit reliability, one is to choose only the best components and the other to reduce the numbers used. Here difficulties arise for although there are many excellent component alternatives it is only rarely that there becomes available a device which will, without sacrificing performance, allow big component saving.

Trochotron Beam Switching Tubes are such devices.

With the 28V VS.10.K. the Ericsson range has been further extended to give Trochotron reliability at low voltage working and here again component saving is remarkable. For instance, in conventional transistorized decade counters with visual readout, transistors and diodes may number about 90, whereas using the VS.10.K Trochotron this total is reduced by about *ninety* percent.

If, therefore you are concerned with counting, frequency dividing, timing, programming, gating etc., make sure you get greater reliability with fewer components by using Ericsson Trochotron Beam Switching Tubes.

28 V TROCHOTRON VS 10 K

Heater	**6.3 or 28.0 V**
Max. spade to cathode voltage	**30 V**
Min. spade to cathode voltage	**24 V**
Target current	**2.0 mA nom.**
Counting speed	**1 Mc/s**

The whole range of Trochotrons is being colour coded for ease of identification. VS.10.G-Red. VS.10.H-Yellow. VS.10.K-Green.

For booklet and leaflets please write to:-

TUBE DIVISION
BEESTON NOTTINGHAM

ERICSSON

ERICSSON TELEPHONES LIMITED · HEAD OFFICE · 22 LINCOLN'S INN FIELDS LONDON W.C.2

AT last it's beginning

to dawn on people that we don't

just make the world's

finest TV and Radio sets (as they put it)

We also do some pretty advanced electronic equipment for

industry—for instance, there's our new range of SOLID-STATE

D.C. AMPLIFIERS that everybody keeps asking us about.

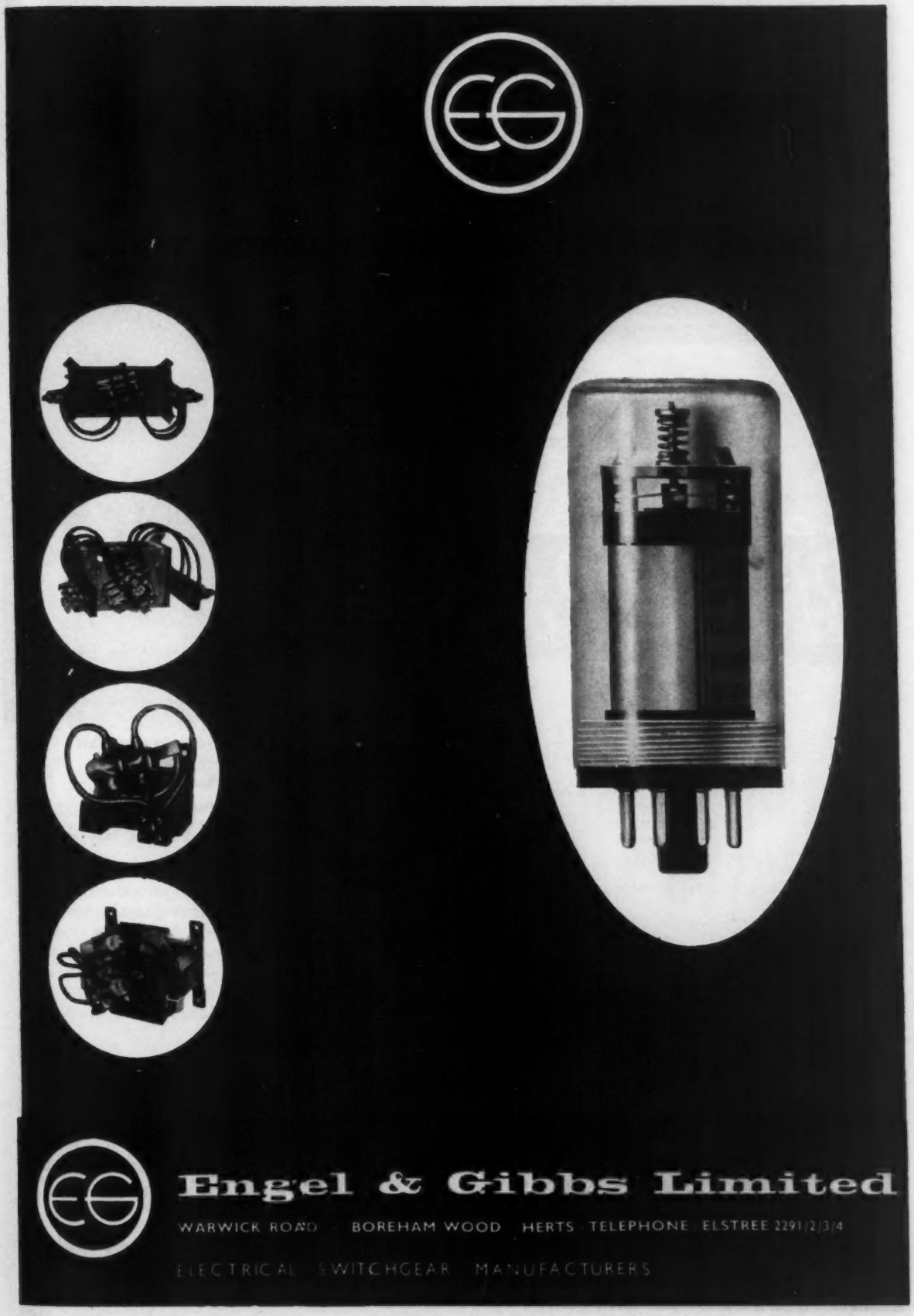
If you're interested (and we think you ought to be)

please let us have your *name and address, too.*

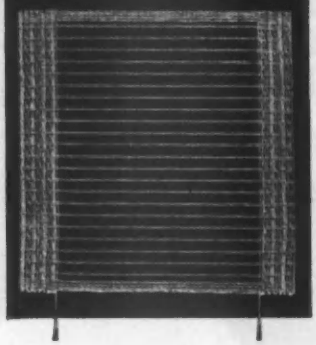
MRC 2001	Trip Amplifier (thermocouple or D.C. millivolt input)
MRC 2002	On-off controller (thermocouple or D.C. millivolt input)
MRC 2003	On-off controller (bridge input—excitation for transducer built in)
MRC 2004	Trip amplifier (bridge input—excitation for transducer built in)
MRC 2005	D.C. amplifier (to drive meters, recorders etc. Also with high voltage output)

MURPHY RADIO LIMITED · ELECTRONICS DIVISION
WELWYN GARDEN CITY · HERTS · Telephone: Welwyn Garden 3434

CAC1C

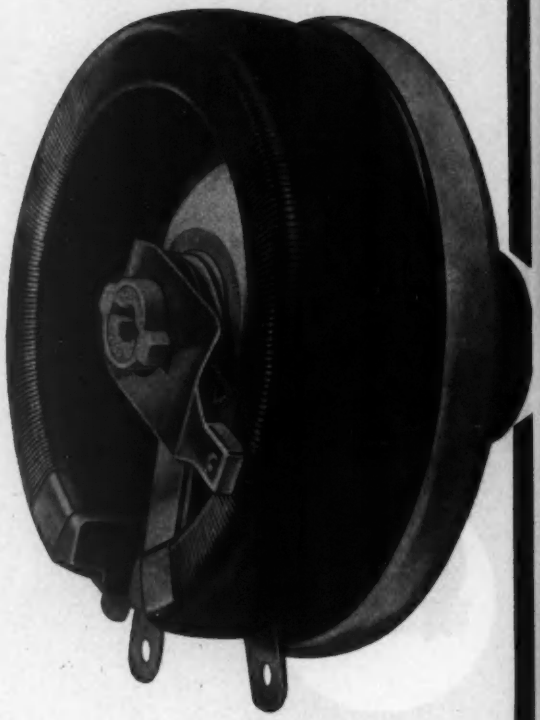

Engel & Gibbs Limited
WARWICK ROAD BOREHAM WOOD HERTS TELEPHONE ELSTREE 2291/2/3/4
ELECTRICAL SWITCHGEAR MANUFACTURERS

✳ *A Cressall asbestos woven net. One of many types developed and backed by 45 years' experience.*



...from the largest
...to the smallest ✳

RESISTORS



✳ *A Cressall Torostat. A toroidally wound vitreous enamelled rheostat for long service and accurate control*

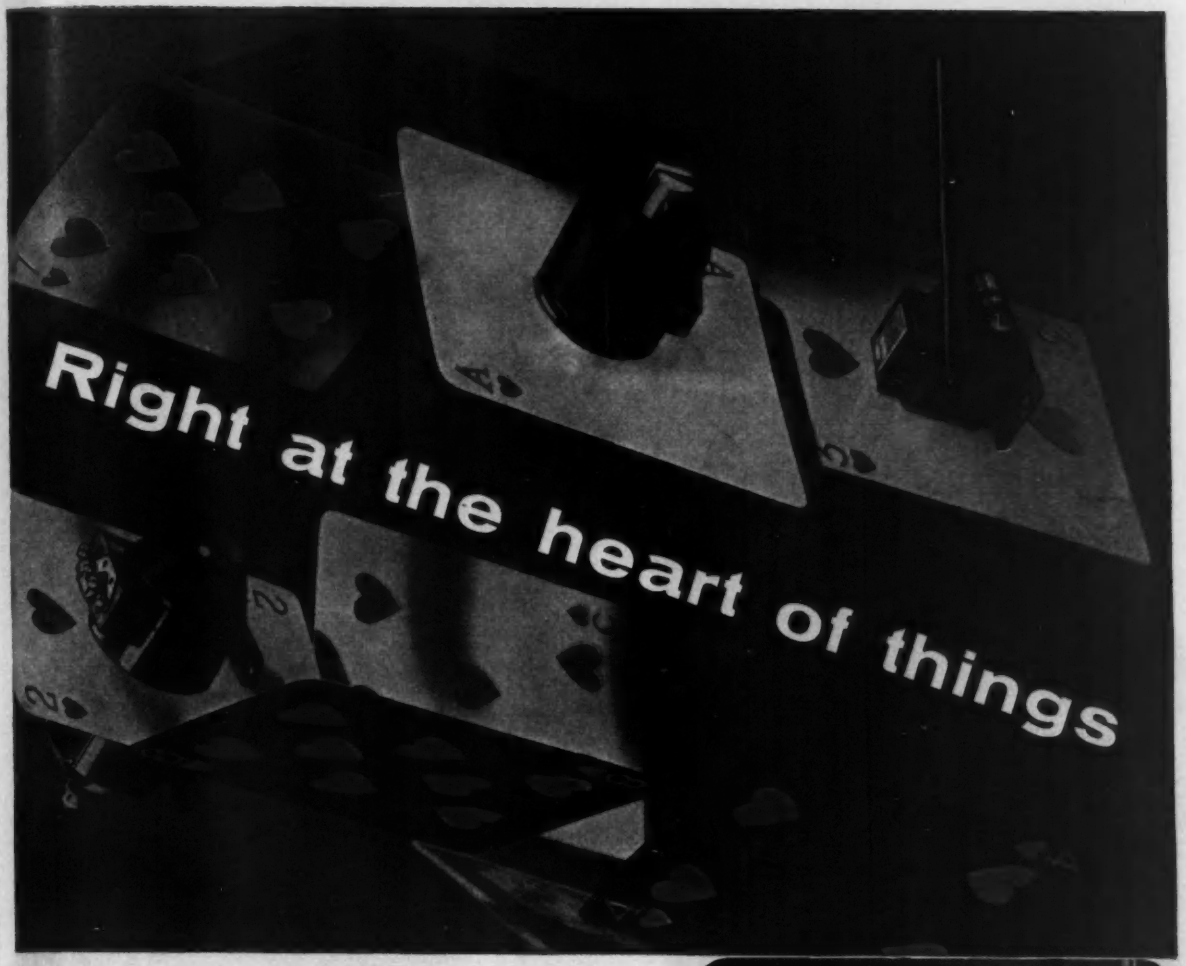
Expamet-Cressall make and supply electrical units to handle every electrical loading from over 20,000 kilowatts to as low as 4 watts . . . whilst it is unlikely that you will require the larger resistors, it is good to know that in Expamet-Cressall you have a simple, reliable organisation, more than equipped to meet all your specialised needs.

EXPAMET-CRESSALL go together all the way

Expamet Cressall

The Electrical Division of The Expanded Metal Company Ltd.

London Office: 16 Caxton St., London, S.W.1. Telephone: ABBey 7766.
Works: Stranton Works, West Hartlepool. Telephone: Hartlepools 5531.
The Cressal Manufacturing Company Ltd., Eclipse Works, Tower St., Birmingham 19. Telephone: Aston Cross 2966.



WESTOOL SOLENOIDS

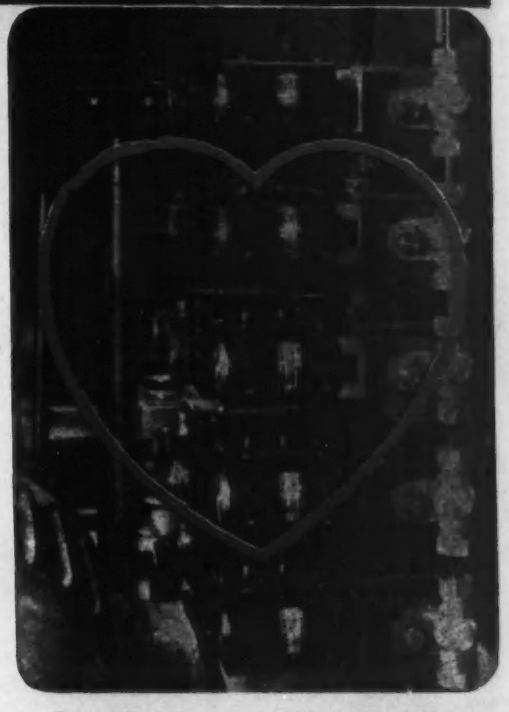
... streamlined for streamline production layouts. Each unit, conveniently compact, easily incorporated into any control system — remote, automatic or push button. Action instantaneous and certain.
The range of both types — AC and DC — is wide indeed; the standard the best throughout.
Send for technical data sheets.

WESTOOL LIMITED

ST. HELEN'S AUCKLAND, CO. DURHAM
Telephone: West Auckland 551 (6 lines)
Telegrams: Solenoid, West Auckland

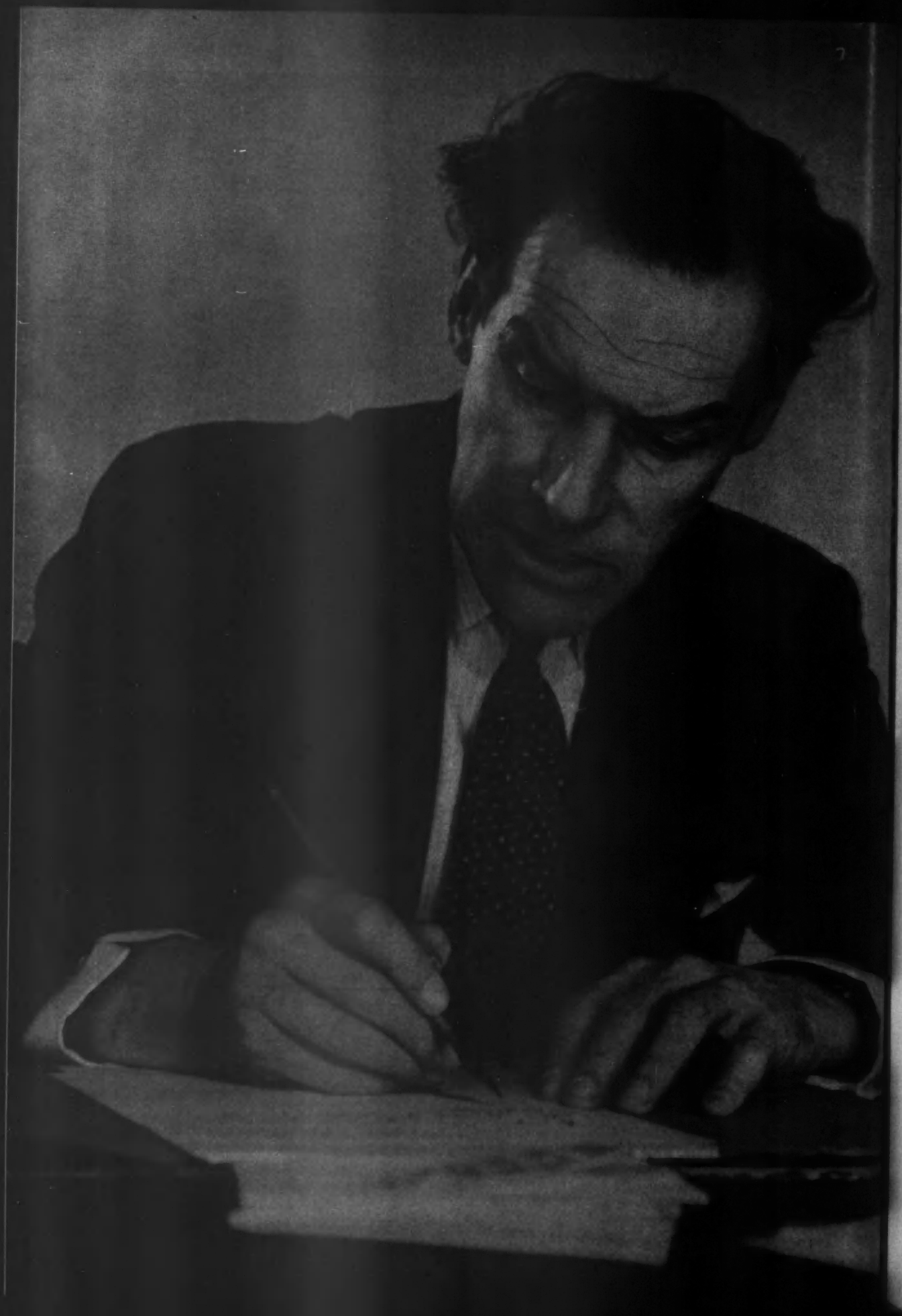
LONDON
2 Ashley Place, Carlisle Place, S.W.1. *Telephone: Victoria 7301/2*

BIRMINGHAM
Silhill House, 2241 Coventry Road, Sheldon, Birmingham, 26
Telephone: 5121/2



Bank of Westool Solenoids operating hydraulic valves. Photograph by courtesy of Towler Brothers Ltd, Leeds.

TIB. 138



Dear Sir,

Why have you the exasperating habit of . . .

Control's editorial department is largely staffed with scientist-journalists, but this does not mean that they are interested only in technical matters.

They write with pleasure about people's triumphs and report their comings and goings. They also enjoy reading and answering the many letters they receive from readers.

Most of these letters are about technical subjects and are, so to speak, neutral in tone. Many are complimentary. Some are critical. A few are penned in the strongest terms.

The Editor publishes some. He welcomes and takes note of them all.

When a reader pays us the compliment of taking the trouble to write it behoves us to sit up and take notice.

Corresponding and so-far-non-corresponding readers are reminded that renewals of subscriptions sent, say, two months in advance help us to keep up more accurately with our growing print demands.

There is something here

for every industry where temperature has to be measured

Approximately 900 'Pyrotenax' thermocouples, with 'Pyrotenax' 2 and 4 core copper-constantan compensating leads and standard 7 core cables, were installed for power and temperature instrumentation in the atomic reactor where these photographs were taken. The cogent reasons for specifying 'Pyrotenax' thermocouples on a job like this are equally valid in many industrial applications—as manufacturers of resins, paints, plastics, textiles, colour and chemicals, and a host of other products have discovered, for 'Pyrotenax' thermocouples possess all the qualities listed on the right.

- **EASILY BENT TO SHAPE**
- **IMMUNE FROM THERMAL SHOCK AND MECHANICAL DAMAGE**
- **SMALL OVERALL DIAMETER**
  permits use in restricted spaces allowing simultaneous readings at different points, where normally only one conventional type could be sited, and generally
- **NO ADDITIONAL PROTECTIVE SHEATHING REQUIRED**
- **RAPID RESPONSE RATE**
  comparable with that of mercury-in-glass thermometer.
- **LONG LIFE**
- **INEXPENSIVELY REPLACED**
  they may be used at temperatures far in excess of those normally permitted for economic operation.

PERFECTED BY EXPERIENCE

Pyrotenax

m.i. THERMOCOUPLES

The use of the trade name 'Pyrotenax' is exclusive to the products of this Company and its associates.

PYROTENAX LIMITED HEBBURN-ON-TYNE • Tel: Hebburn 83-2244/8

LONDON: *VICtoria 3745* BIRMINGHAM: *Midland 1265* MANCHESTER: *Deansgate 3346/7* LEEDS: *Leeds 27826* GLASGOW: *City 3641/2* CARDIFF *23689* NOTTINGHAM: *Nottingham 83905*

For better service from any air line

Any air control system incorporating cylinders and valves, or which operates tools and equipment, will give better service if the air is properly filtered, the pressure is regulated to the job and adequate lubrication is provided. The Schrader LUB-AIR-ATOR is a combination of three units which perform these functions automatically, ensuring better and safer operation and longer, care-free service. It prevents wastage of high-pressure air and reduces frictional wear on installations and equipment. The LUB-AIR-ATOR is easily maintained. It has no moving parts to wear and can be serviced without disturbing the pipe connections. Available in three sizes with various flow capacities.

AIR LINE FILTERS
Clean the air supply of rust, dirt and moisture. Sintered bronze filter unit, whirling action baffle plate and bowl, easily cleaned without disturbing piping.

AIR PRESSURE REGULATORS
Reduce and maintain line pressures to the actual requirementsat any point. Outstanding for higher capacity, faster response and lower pressure drop under loading.

AIR LINE LUBRICATORS
Provide lubrication protection for cylinders, valves and pneumatic equipment. External flow adjustment. Visible oil level. Refilled without shutting off the air.

Schrader
LUB-AIR-ATOR

Send coupon TODAY for full details

To: A. SCHRADER'S SON, Air Control Products Dept. C, 829 TYBURN ROAD, ERDINGTON, BIRMINGHAM, 24

Please send details of Schrader LUB-AIR-ATOR

NAME.....

ADDRESS.....

.....

13

SILICON POWER

Ref: SP	2N1479 2N1481	2N1480 2N1482	2N1483 2N1485	2N1484 2N1486	2N1487 2N1489	2N1488 2N1490	UNITS (max)
Collector-base voltage	60	100	60	100	60	100	volts
Collector-emitter voltage with base open	40	55	40	55	40	55	volts
Emitter-base voltage	12	12	12	12	10	10	volts
Collector current	1.5	1.5	3	3	6	6	amps
Transistor dissipation At case temp. 25°C	4	4	15	15	60	60	watts
At case temp. 100°C	2	2	7.5	7.5	30	30	watts

Write for Data Sheets quoting reference to:

ASSOCIATED TRANSISTORS LIMITED

SHAFTESBURY HOUSE · SHAFTESBURY AVENUE · SOUTH HARROW · MIDDX · BYRON 9571

A.T.4

SILICON MESA

Ref: SM	2N1491	2N1492	2N1493	UNITS
Collector-emitter voltage with emitter-base reverse b'ased	30	60	100	volts
Emitter-base voltage	1	2	4.5	volts
Collector current	50	50	50	mA
Transistor dissipation Free air $T_A = 25°C$	0.5	0.5	0.5	watts
$T_A = 100°C$	0.25	0.25	0.25	watts
Heat sink $T_c = 100°C$	1.5	1.5	1.5	watts
Alpha cut-off frequency	250	275	300	Mc/s
Typical power gain at 70 mcs	15	15	12	dB

OCTOBER 1960 VOL. 3 NO. 28 CONTROL

Switching to the solid state

AFTER THE EARLY over-selling of computers, and the subsequent disillusionment of some ill-advised buyers, we are not surprised to find today that there is some resistance to the introduction of process control by on-line installations. In the hope of illuminating the discussion a little, and perhaps of helping on a rational adoption of process-control computers, we have already published several articles on the subject (the latest appears in this issue) and there are more to come.

The most worrying thing about it all, we think, is the problem of reliability. On this page last month we were rather critical of those 'cautious captains' of industry who do not let their control engineers try to improve dynamic performance in their works, but we may have been unkind in our strictures. Costly plant, on which outage may be fearfully expensive, is not handed over lightly to a man with a gleam in his eye, and most managers would probably prefer to see their competitors try it first. In these circumstances it is not difficult to understand a reluctance to move from simple to more sophisticated control systems. Greater complexity can be justified only if correspondingly greater reliability is achieved. In fact, we have heard it suggested that some very expensive mistakes are being made at the present time because this simple truth has been overlooked.

There is of course ground for faith that reliability can be raised sufficiently for control systems to become much more complex than they are at the moment. Solid-state devices are on the whole fulfilling their early promise, and perhaps they are the control engineer's brightest hope. Not everybody will accept this view at once, we know, and there is still a tendency to use relays and other electromechanical devices in certain industrial systems. Flexibility and economy do seem to be possible with relays where high speed is not needed, and complicated switching arrangements can be made very easily; but anybody who has to spend much of his time on the telephone will testify to the occasional mistake in the machinery. Relatively rare though such failure may be, its occurrence is sufficiently frequent to frighten many plant operators away from complex electromechanical automation, and we sympathize with this fear. The standard accepted in telephone exchanges is just not good enough for advanced control systems.

Although nothing looks simpler than a mechanical switch, one may soon be intimidated by a study of the physics of electrical contact. Because of wear, component life is determined by the number of operations rather than by long-term aging. Dirt slips between the contact surfaces, and globules of molten metal form at the intensely heated points where the contacts finally break. Contacts bounce and the springs behind them vibrate: we have seen hardened engineers flinch when shown an ultra-slow-motion film of this kind of thing.

Undoubtedly relays are easy to understand, and they have given excellent service in many fields. Where they do not have to function often, or where the occasional failure does not matter, they are probably among the best of solutions. (Even then it is better to make them sealed and expendable, to allow for the kind of maintenance man who goes on adjusting contacts for too long.) But investigation of failures, however infrequent they may be, can be difficult and costly. Certainly one can try to design a relay system so that failure is always 'to safety' and so that faults always show up quickly, but the extra circuitry required may be such as to destroy the principal advantage that one hopes to gain with electromechanical devices—simplicity.

It is possible that control systems full of clicking relays will have to be ruled out altogether in the most advanced applications. Of course one must be properly hesitant in saying this, for it is also possible that solid-state devices will in time prove to be less close to the ideal than at present they promise to become; but computer designers have moved away from relays, and they are finding that solid-state devices are the answer in most cases. There are not a few situations where the control engineer would do well to take a leaf out of the computer-designer's book—indeed, there are places where this would save the control engineer from getting a bad name. We would suggest that popular preference will switch to the solid state rather sooner than some of us have been prepared to expect, and this may well be the decisive step toward general acceptance of process control by on-line computer.

LETTERS to the EDITOR

Jet relays

SIR: Whilst welcoming the 'Look at America' newsletter in your current issue* from our friends Messrs. Shearer, Scher and Reid I would like to draw attention to the much earlier work on the Jet-type fluid relay which appears to have been overlooked by our colleagues across the Atlantic. I refer to the works of Ferner (Die Technik No. 6; 1954, p. 359–365); Ivlichev and Nadzhafov (Automatic and Remote Control; Vol. 19; No. 11, p. 977–88 November 1958) and Zalmanzon and Semikova (Ibid Vol. 20; No. 4; p. 431–452 April 1959). Each of these papers describes a similar if not identical device and in these days of an ever increasing volume of news items I ask that we restrict newsletters and similar topics to things which are news and omit those which are several years old.

Harlow, Essex D. E. TURNBULL

● *Our American Correspondents write: 'Constructive criticism of the "Look at America" newsletters such as Mr. Turnbull's are heartily welcomed. The authors are fully aware of the earlier German and Russian work concerned with fluid relay devices. A striking difference does exist, however, between the past work and the more recent American work in progress (i.e., unpublished work of the Diamond Ordnance Fuze Laboratory and recent work at M.I.T.) The Germans and Russians have primarily directed their efforts toward the development of fluid relay and computing devices (primarily signal transmission devices) utilizing conventional nozzle-flapper and diaphragm components. The excellent work of Zalmanzon and Semikova extended this work to include the use of nozzle-pipe elements and the characteristics of very low velocity jets to perform computing and relay functions.*

'In contrast, the American work has been directed toward the development of a new and special class of fluid relay devices, for both *power and signal transmission; with* no moving parts. *These devices employ special methods of boundary layer control and utilize the characteristics of bistable or tristable jets and boundary layer "lock-on."*

'It is interesting to note that we saw some as yet unpublished results of recent work at IAT, Moscow, during the recent IFAC Congress which involves bistable jet relay devices. They are similar to the American devices, and are apparently an outgrowth of the earlier work by Zalmanzon and Semikova mentioned by Mr Turnbull.'—EDITOR.

* August, p. 110 ff.—ED.TOR.

Full value for a word

SIR: It is pleasing to see the processes of disputation can sometimes bring reasonable people together instead of driving them apart. I believe, after reading Mr. Rudkin's second letter,* that he and I can agree.

Firstly, he requires that the dividing point between levels of sophistication in control systems be established with precision before the one is called "automatic" and the other "cybernetic". I fully accept that. Most of my book *Cybernetics and Management* is devoted to the same thesis, and I have also offered a rigorous statement of the dividing line in the precise language of symbolic logic on p. 37 of *Proceedings of the First International Conference on Cybernetics (1956).*

The second point is whether, given that a distinction has been set up, I have adhered to its provisions. Mr. Rudkin says that I have applied the broader word to the narrower field, but this impression may well be due to the exclusion from my paper (as published in *Control*) of the whole of the scientific model on which it is based. The full version of the paper, in which the model takes up half the space,† shows how the control system I describe is specifically designed as an artefact of the brain—and nothing could be more genuinely cybernetic than that, as I am sure Mr. Rudkin would agree. In fact I strongly applaud his determination to get full value for the word cybernetics, which is much abused.

Finally, on the point of grammar, I happily accept Mr. Rudkin's view that there *ought* to be an adjective, deriving from the noun "cybernetics", which could more readily be distinguished from the noun. There would then be no risk of confusion. In our imperfect language, however, the noun and its adjective are often identical; and usage has already firmly established that the adjective from "cybernetics" is just "cybernetic". The man (Wiener) who actually named the new science, and the men (McCulloch, von Foerster and the rest) who blazed the trail with him, all use the word in the way I use it. And, if I may be forgiven for making the point (for it seems a little like hitting below the belt), these same authorities seem perfectly satisfied that the work which occasioned this debate is in fact a cybernetic control system.

The United Steel Companies STAFFORD BEER

* 'Letters' last month, p. 80.—EDITOR

† Mr Stafford Beer is here referring to the set-theoretic formulation of the brain model which he gave in his paper *Towards the cybernetic factory*, Symposium on Principles of Self-organization, Illinois University. The symposium was reported on p. 118ff of *Control* last month.—EDITOR

PUBLISHER'S COLUMN

Who's who in control

One of the many interesting features of the Industry Guide and Digest *number of* Control *(a free copy of which will be sent to all subscribers shortly) is the 'Who's Who'. The entries for this have been painstakingly collected over many months. First we approached every firm listed in the* Control Buyers' Guide. *Next we invited users and the various educational and research centres to name their candidates. And finally we asked consultants and other free agents to submit their drafts.*

One man we know was offended because the light-hearted sample entry that we sent round was invented for a 'Who' born in Wigan, and this apparently is no joke. He, alas, will not appear in our first edition. Pretty well everybody else seems to have approved of the idea, and our problem has been to deal with the excess of candidates. Naturally we are sorry that not everybody could go in, but we feel sure that the reason for this will be understood—limited editorial space.

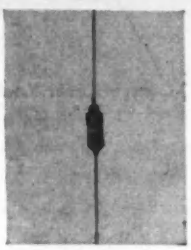
All in all, we think that the Control Industry Guide and Digest *will be an excellent reference to have on your shelf, as much for the 'Who's Who' as for the other features.*

Si
ZENER

Voltage Reference Diodes

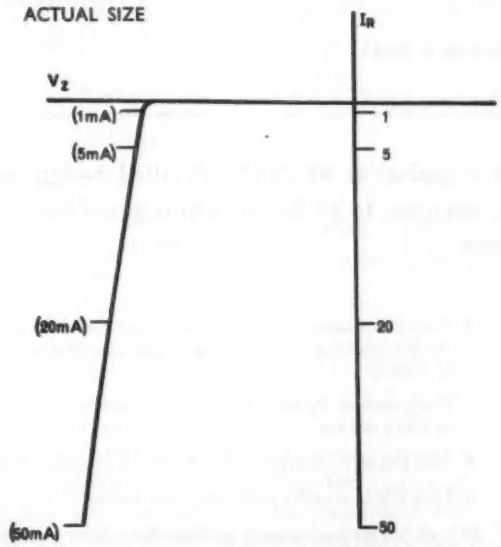
SMALL DIMENSIONS · LARGE DISSIPATION · LOW SLOPE IMPEDANCE

3·3-15 VOLTS · 400 mW @ 25°C · 80 mW @ 125°C

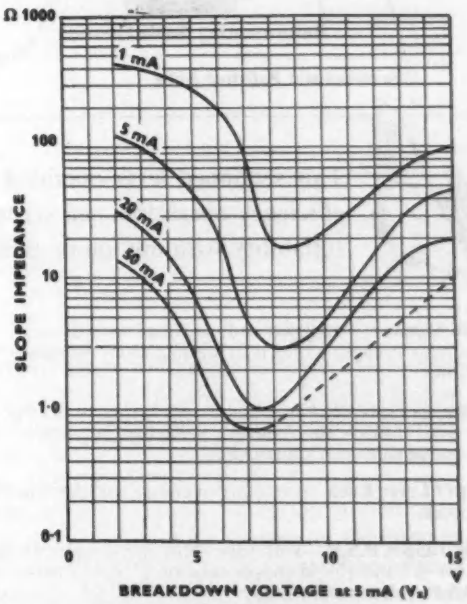


ACTUAL SIZE

NEW FROM TEXAS—The 1S7000 Series—to replace neons and standard cells in a wide variety of voltage reference circuits. They allow designers maximum flexibility in circuit design of equipment for stable, reliable operation at elevated temperatures. SMALL SIZE, standardised hard-glass hermetically-sealed case, plus a high degree of reliability make these devices particularly suitable for introduction into AUTOMATIC assembly lines. 1S7000 Series Zener Diodes are available in two ranges (5% and 10% tolerance ratings), meet CV specifications and may be ordered in PRODUCTION QUANTITIES—NOW.



REVERSE CHARACTERISTIC



TYPICAL SLOPE IMPEDANCE

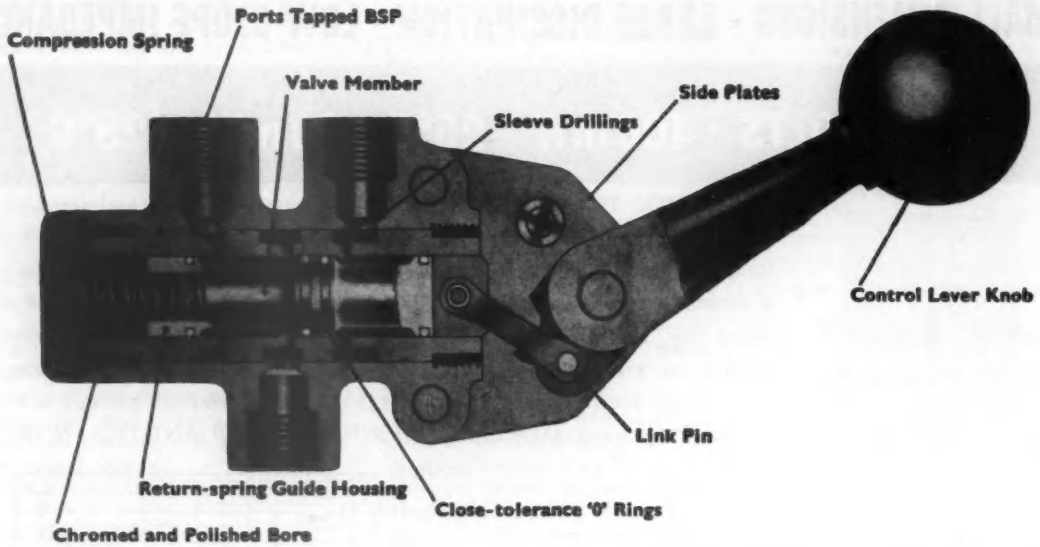
Write for Data Sheets and Application Information on these and other TEXAS devices.

TEXAS INSTRUMENTS
LIMITED
DALLAS ROAD BEDFORD ENGLAND
BEDFORD 68051 CABLES: TEXINLIM · BEDFORD 91/A3

Designers of production machines specify

MAXAM

for Quality and Precision



This sectioned lever-operated valve is typical of MAXAM detailed design for high-efficiency operation, and scrupulous attention to all features that guarantee complete reliability with minimum maintenance.

★ **Valve Member**—designed and machined to provide maximum strength whilst offering minimum resistance to air flow.

★ **Return-spring Guide Housing**—assists spring to provide true axial thrust when returning valve member, thus preventing side wear on packings.

★ **Control Lever Knob**—available in colour for identification purposes.

★ **Ports Tapped B.S.P.**—with tube form providing an airtight seal for $\frac{1}{8}$" and $\frac{1}{4}$" o/d copper tube on $\frac{1}{4}$" B.S.P. and $\frac{1}{2}$" B.S.P. valves respectively.

★ **Chromed and Polished Bore**—for improved wear characteristics and exceptionally low frictional resistance.

★ **Close-tolerance 'O' Rings**—these are specially manufactured to provide positive sealing within recommended pressure range.

★ **Sleeve Drillings**—specially machined and polished to reduce packing wear to a minimum and provide maximum air flow.

★ **Compression Spring**—of adequate proportions to ensure positive action.

★ **Side Plates**—reversible for alternative operating conditions.

★ **Link Pin**—ensures positive direct action.

66% of current production in machine shops is for companies whose designers—with experience of MAXAM product quality, performance and reliability—have planned their future flow production machines with MAXAM Fluid Power Equipment in mind!

MAXAM POWER LIMITED

Distributed by:
Holman Bros. Limited, Camborne, England; Camborne 2273 and at 44 Brook Street, London W.1; Hyde Park 9444
Also in Birmingham · Cardiff · Glasgow · Peterborough Sheffield. Australia · Canada · East Africa · France India · South Africa · Spain · U.S.A. · West Africa. With Agents and Representatives throughout the world.

THE HOLMAN GROUP

For completely reliable operation with maximum economy—specify MAXAM *Fluid Power Equipment*

SUBSCRIPTION RATES
(all post free)

INTRODUCTORY RATE £1.10.0
—available only to individuals who have not previously subscribed

NORMAL RATE £2.2.0
(U.S.A. and Canada) $8.00

3 YEAR RATE £5
(U.S.A. and Canada) $20.00

STUDENT RATE £1.0.0
— available to engineering students and apprentices

Please send me CONTROL

starting with the.....issue and invoice me later at the following rate: (tick appropriate box)

☐ **INTRODUCTORY RATE** £1.10.0 ☐ 3 Year Rate £5.0.0 ($20.00)

☐ Normal Rate £2.2.0 ($8.00) ☐ Student Rate £1.0.0

NAME .....

ADDRESS .....

.....

FIRM, ESTABLISHMENT OR COLLEGE .....

Existing readers: A special group rate is available at a substantial reduction for three individuals subscribing together. ☐ Tick here for details

(H.P. 3154)

Postage will be paid by the licensee

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Service Licence WD 1823

CONTROL
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

VIEWPOINT

The National Engineering Laboratory's Director, Dr D. G. Sopwith, feels that the results of Government research should be applied to better advantage, and calls for . . .

MORE D.S.I.R.-INDUSTRY COLLABORATION

The research stations of the Department of Scientific and Industrial Research have been set up, to quote the D.S.I.R. Act, 1956, 'for investigation and research relating to the advancement of trade and industry'. It is therefore incumbent upon their directors not only to see that research work of high quality is done, but that it is of interest—either immediate or potential—to industry and that its results are applied by industry. Thus three stages are involved: (1) the identification of problems, (2) their solution, and (3) ensuring that appropriate use is made of the solutions by industry. The last of these is by no means the least difficult, and I propose to offer a few thoughts on it.

Until fairly recently it has been the practice to report the results of research work in the scientific or technical press, and to hope that industry will then apply the results in their own practice. Publicity has been given to the work of the stations by the holding of open days, by participation in appropriate exhibitions, by general lectures on the work of the laboratory as a whole or on particular sections, and by other similar means. These all play an essential part in getting the results of research over to industry, but experience has shown that they are not in themselves sufficient.

How then can use of the results be ensured? It would appear that one very good method is that of direct collaboration between the laboratory and individual industrial firms, with the object of producing an instrument or piece of equipment embodying the results of research. This is a policy which has been increasingly adopted recently at the National Engineering Laboratory, and two examples may be quoted which should be of interest to readers of *Control*.

The first was the application of moiré fringes to the correction of errors in a gear-hobbing machine. In this the phase difference between pairs of optical gratings, caused by errors of relative motion between components of the machine, was used to correct the movement of one of the components through a servo-system. Initial results have shown a fourfold increase in the accuracy of the gears cut. The second example was the application of an inexpensive and flexible hydrostatic drive to a vertical boring machine. Both these were developed in collaboration with industrial firms, and in addition to the immediate application of the work implied in the actual machines themselves, their demonstration at the recent International Machine Tool Trades Exhibition has been very successful in arousing interest on the part of other firms.

This would seem to be potentially a very fruitful method of increasing the extent to which the results of research are applied. That extent, multiplied by the 'worth-whileness' of the objective aimed at, is a measure of the value of the research. There is however one danger to be borne in mind; success in applied work of this kind may involve a temptation to increase unduly the proportion of effort devoted to it at the expense of the essential fundamental and basic work which alone renders it possible. The directorate, therefore, must always try to maintain the correct balance between basic and applied research and develoment. A proportion of development work is nevertheless a valuable stimulus, not only to industry but also to research.

D.G. Sopwith

A clear description of the processes and their control—plus some sharp criticism for manufacturers of instruments and process-control equipment. This article is a plain challenge to the industry

Controlling the manufacture of laminated plastics

by **D. LIDGLEY, D. C. LOWE** *and* **D. A. MACKINTOSH**

Formica Ltd

LAMINATED PLASTICS WERE FIRST MANUFACTURED COMmercially in the 1920s, soon after the invention of the first truly synthetic resin by Baekeland, and the years up to the beginning of the last war saw a slow but steady increase in their use. During that period they were employed mainly for electrical insulation, and this application accelerated rapidly during the war with the large increase in the production of electronic components for the military. They also found substantial employment as constructional materials for engineering applications, and their use was encouraged by the shortage of traditional materials.

Since the war the use of laminated plastics for decoration has increased enormously, to the extent where their production has greatly outstripped that for purely industrial applications.

In the last decade, recently-developed synthetic resins have supplemented the phenol, urea and melamine formaldehyde resins which still form the bulk of the resins used for this purpose, and we have also seen increased use of polyester resins reinforced with glass fibre.

WHAT LAMINATED PLASTICS ARE

Laminated plastics are really a special class of reinforced plastics material in which the fibre reinforcement is introduced in the form of a number of layers or laminae of fibrous sheet materials. After impregnation with the synthetic resins these laminae are consolidated, usually by the application of heat and pressure, into a homogeneous sheet. They are characterized by a reasonably constant distribution of resin throughout the whole of the finished sheet, and are thereby distinguished from resin 'sandwiches' such as plywood, in which the resin merely acts as an adhesive for the individual plies.

In the case of a construction of this nature the mechanical properties of the final sheet—for example the tensile strength—are the sum of the properties of the individual plies, whereas in the case of laminated plastics a considerable improvement over the individual properties of the components is achieved. This is particularly so in the case of thermosetting resins (i.e. those which are permanently hardened by heating) since these tend to be very hard, inflexible, rather brittle products when used alone, and their reinforcement with fibrous materials helps to confer the toughness, flexibility and strength of the fibres whilst retaining most of the desirable properties such as hardness, moisture and chemical resistance, and electrical insulating properties of the pure resin.

Thermoplastics, i.e. those materials which can be repeatedly softened by heating, are not usually used in laminated plastics since their properties are not normally enhanced by fibre reinforcement.

HOW LAMINATES ARE MADE

The basis of the manufacture of a typical plastics laminate is simple, and consists in impregnating the sheets of a fibre (such as paper) with a synthetic resin in solution, and stoving the impregnated sheets to drive off the solvents and advance the 'cure' of the resin. Then a number of plies of the impregnated sheets are stacked between the platens of a hydraulic press and consolidated under elevated temperatures and pressures.

During this latter stage the resin is caused to melt or flow and fill all the voids between the fibres, and this is followed by the permanent hardening effect of the elevated temperatures. Provided that the process has been carried out properly the product is a homogeneous, void-free sheet in which it is no longer possible to separate the individual laminae.

The use of a number of individual plies of impregnated material in the assembly makes it possible to confer substantially different properties on different parts of the thickness of the laminate, and in the case of decorative laminates, with which this article will be mainly concerned, the assembly consists of a number of sheets of Kraft paper impregnated with phenol formaldehyde resins surmounted by a decorative sheet. This has been rendered opaque and coloured by mixing pigment with the cellulose fibre during the paper manufacture and by printing a pattern upon the surface using specially developed printing techniques. The sheet is invariably impregnated with melamine formaldehyde resins, which are completely colourless and transparent. It is normal to use in addition a cover sheet or overlay of very pure cellulose paper, heavily impregnated with melamine resin, which becomes almost entirely transparent during pressing. As a result the properties of the surface are characteristically those of a cured melamine formaldehyde resin, and the colour and pattern of the printed sheet is protected from abrasion and chemical attack by the thin, transparent layer of fibre-reinforced melamine resin.

In the case of thermosetting moulding compounds, in which the fibrous or other reinforcement is randomly mixed with the resin and laid into the mould in the form of powder or granules, a very large range of properties in the final article can be obtained by the choice of resin and fibre, the relative proportions of each, and the process of manufacture. A similar versatility applies to the manufacture of laminated plastics, but with an additional faculty for combining the desirable surface characteristics of one combination with the mechanical characteristics of another, by lamination.

It will thus be seen that the number of variables in the manufacture of laminated plastics is very large. Unfortunately, certain properties are also extremely sensitive to minor variations in the process, with the result that—whilst the essence of the process is simple—the production of consistent products having the optimum combination of attainable properties requires the closest possible control of all the variables at each stage of the manufacture. The stages in the manufacture of these materials are described below.

Raw materials

The main raw materials used are synthetic resins which are either purchased from resin suppliers or manufactured by the laminator from the basic raw materials; also, paper and other fibrous sheet materials, such as cotton, asbestos or glass fabrics; together with the assorted armoury of modern industry, ranging from boiler-feed chemicals to tungsten-carbide-tipped saw blades.

The main controls exerted over the raw materials are laboratory tests designed to ensure that those properties essential for the production of consistent products are maintained within the closest possible limits.

Resin manufacture

It is now customary for the larger manufacturers of laminated plastics to make at least the major proportion of the resins which they consume. The manufacture of phenolic, urea and melamine formaldehyde resins for paper impregnation each follow broadly similar lines.

The stainless-steel reaction vessel is double-skinned to permit external heating and cooling, and has about

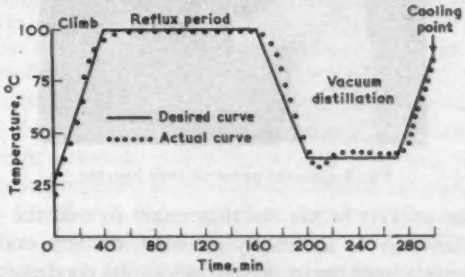


Fig. 1 Control relationship between time and temperature during manufacture of phenolic resins

1000–2000 gallons capacity. There are facilities for stirring, atmospheric and vacuum distillation and reflux, and the loading and unloading of liquid and solid charges.

The reactants, such as phenol and 37% formaldehyde solution, are weighed and loaded into the cold reactor together with the catalyst. The reaction is brought about by heating. As in the case of all synthetic resins, the phenol formaldehyde resins are not pure stoichiometric compounds but a mixture of many different chemical units of widely varying molecular weights. Thus, in order to produce a consistent material, which is essential for subsequent processing operations, it is very important that the time/temperature history of the resin is carefully controlled. A typical curve obtained is shown in the illustration (Fig. 1), and it will be seen that the aim in this case was to climb at a constant rate to the temperature of reflux (approximately 100°C) and to hold this temperature for the precise length of time required, after which the resin was cooled and vacuum-distilled to remove a proportion of the water introduced by the formalin solution and by the condensation reaction.

The traditional method of controlling the reaction is for the operator to plot the temperature of his reaction mixture against time on graph paper showing the desired time/temperature curve, and to maintain the desired rate of climb by manipulating alternately the steam control valve and the cooling water valve. The latter is necessary during the early part of the reaction to counteract the exothermic reaction, which occurs at approximately 80°C and which, if allowed to get out of hand, might cause the entire charge to go solid in the vessel or to boil so violently as to choke the condenser lines.

A number of instruments are used to assist the operator in his task. For example, a multi-point recording potentiometer is connected to a number of thermo-

Fig. 2 Control panel of resin reactor

couple pockets in the reaction vessel so that the temperature may be accurately recorded; the temperatures of the inlet and outlet water lines to the condenser are also recorded as an indication of the rate of heat input at reflux and vacuum gauges are used during the vacuum distillation stage (Fig. 2).

Theoretically, it should be possible for the whole of this reaction to be conducted automatically. Clearly, a dual-acting program-controller would be required in order that the cooling water might be brought in when turning off the steam alone was insufficient to control the temperature-rise, and a liquid flowmeter would be needed to control the rate of distillation during the reflux period (it is obvious that temperature control at reflux temperature cannot be used).

When the vacuum distillation stage was reached, the control of the heat input would have to be linked with the rate of distillation on the one hand (to prevent choking the condenser) and the rate of application of vacuum on the other, since if the vacuum were applied too quickly whilst the charge was still hot, the rapid boiling would cause the charge to froth and be carried over into the receiver.

We have considered for some time the installation of automatic process control of this nature and proposals have been put to us by instrument manufacturers. However, the following circumstances did not encourage us to make the relatively large investment required (about 15% of the total cost of the resin manufacturing plant):

1 The manufacturers were not prepared to give a firm undertaking that their system would function as required, nor to supply on a sale-or-return basis.

2 Our experience with a less ambitious automatic process-control on another resin plant had shown that the one man who should have been freed from manually controlling the process was still engaged in supervising the reaction to rectify the instrument inadequacies.

Impregnation

The paper or fabric is impregnated and stoved on continuous impregnation machines, which are illustrated schematically in Fig. 3. The synthetic resins are reduced to the required viscosity and solids-content by blending them with alcohol or water, and the continuous web of paper or fabric passes under an immersed roller in the tank of varnish and then through some form of metering device, such as a pair of 'doctor' rolls which can be adjusted to give the required varnish pick-up.

The ovens are normally of the hot-air-recirculation type, using steam or high-pressure hot-water heating batteries and air-flows adjusted to maintain the economic ratio of fresh air to recirculated air in the system.

Fig. 3 (below) Schematic diagram of impregnating machine, showing the β-ray gauge and the automatic resin control

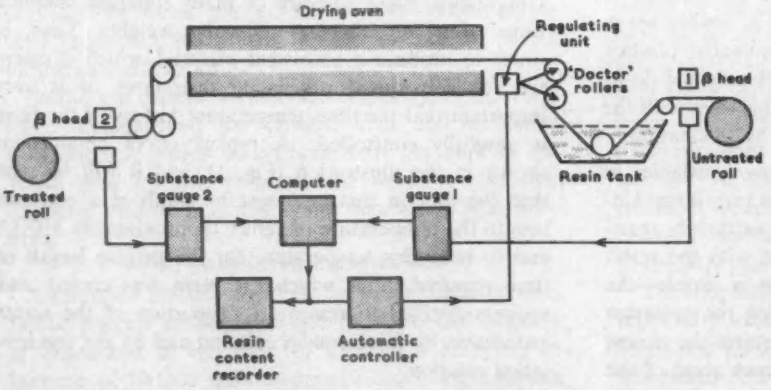
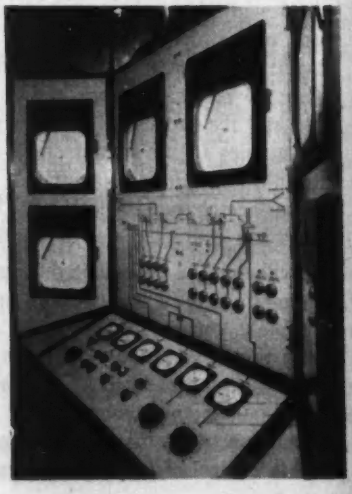


Fig. 4 (right) Control panel of impregnating machine



The hot-air temperatures of each zone of the oven are maintained by a suitable proportional controller. We use almost exclusively Bristol Type-Series-500 in conjunction with a high-pressure hot-water heating system, and these function very well (Fig. 4).

The properties in the treated paper which have to be closely controlled are the resin content, the volatile content and the 'flow' (or degree of cure) of the resin. The latter is closely connected with the volatile content but is also dependent upon the heat history of the resin, and it is generally desirable to remove as much as possible of the free volatile matter without overheating the paper to the degree where the cure of the resin is appreciably advanced.

The customary method of controlling these factors is by cutting samples from the unimpregnated and impregnated material and measuring the resin and volatile content and 'flow' by weight differences. Clearly, the resin content, for example, is calculated by the difference in weight between the impregnated and unimpregnated material.

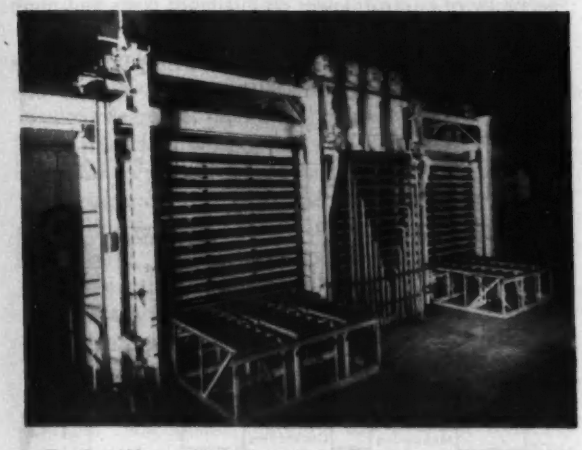


Fig. 5 4000-ton, 12-daylight hydraulic press with automatic preloaders

Since there is an economic limit to the frequency of sampling by this method, it is desirable that non-destructive means of measuring these properties continuously should be available. Some progress has been made in respect to the continuous measurement of resin content and automatic adjustment of the impregnation to maintain this at a constant value. The system consists of two β-ray substance gauges, one of which is placed to measure the weight per unit area of the untreated paper and the other at the reel-up end of the machine. Signals from these two measurements are fed to a computer which records continuously the difference expressed as a percentage of the total weight. By superimposing a controller with a dead zone on either side of the desired resin-content to avoid excessive hunting, it is possible continuously to control the amount of resin applied.

Of equal importance would be the continuous measurement of volatile content and the adjustment of machine speeds and temperatures to maintain this at the desired level. This is a highly complex problem for the following reasons:

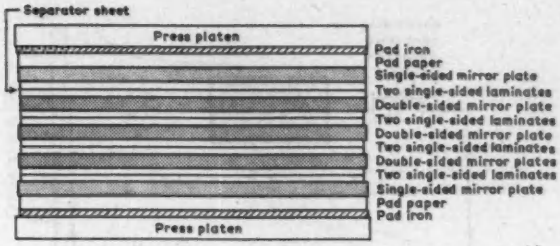


Fig. 6 Typical decorative-laminate-pack assembly

a The volatile content measured by heating a sample at 150°C for five minutes (the conventional method) consists partly of free volatile material (mainly water) and partly of the water of condensation released by the cure of the resin during this heating period. It is inevitable therefore that an entirely different system of control from the present method would be necessary since, in general, we could only expect an instrument to measure the free volatile.

b The free volatile content is very low (usually less than 5%).

c The dielectric and electrical conducting properties of the resin-impregnated paper are completely different from those of unimpregnated paper, and these properties vary considerably for each type of impregnated paper.

We have attempted to measure this property continuously by a variety of devices utilizing the conductivity, dielectric constant, power factor and dispersion factor of the impregnated paper, but insufficient correlation has been found with the important property (free volatile content) to provide a reliable means of control. This problem is an extremely interesting one, upon which we would very much welcome the assistance of an instrument manufacturer who is prepared to develop a means of control with us.

Pressing

The size and complexity of the hydraulic press depend very much upon the grade of laminate being produced. Modern presses for decorative laminates usually have twelve to sixteen 'daylights' or openings between the platens which are up to 10 ft × 4 ft in size.

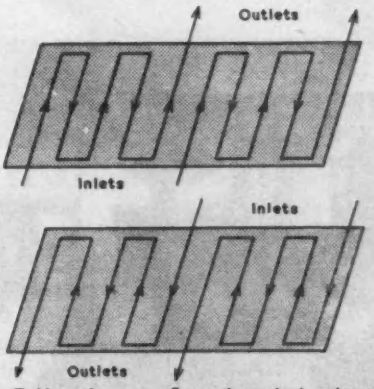


Fig. 7 How the water flows through the platens

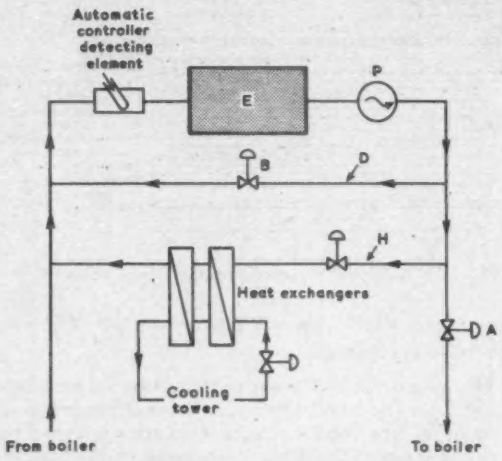


Fig. 8 Flow diagram for press temperature-control

Since the pressures used on the work are of the order of 1 ton/in² the total force exerted can be as large as 6000 tons.

In the interests of economy it is necessary to press as many boards as possible in each press load, and this is achieved by having automatic loading and unloading equipment, so that the whole press load may be changed simultaneously, and by having the maximum number of boards in each 'daylight'. By this means it is normal to produce about a hundred boards in one press cycle of about 1½ hours (Fig. 5).

The consistency of properties and visual appearance are much dependent upon the receipt by each board of a closely similar time/temperature treatment. Moreover, in order to complete the cure cycle as rapidly as possible, and hence secure the maximum output from these very expensive presses, a laminator will always wish to cure his boards as close as possible to the scorching temperature of the cellulose, so the greatest accuracy of temperature control is required.

A typical 'pack' assembly between one pair of the platens is shown in Fig. 6. The platens are drilled so as to give an even heating effect over the whole area when steam or high-pressure hot water is pumped through them. This is achieved in the manner shown in Fig. 7, in which it will be seen that the counter-flow of the heating medium is arranged to compensate for the heat loss to the platen body.

It will be obvious that the rate of temperature-rise in the centre board of a pack will be much lower, especially at the start, than in the outside boards. This is partly compensated by the corresponding rate of cooling at the end of the cycle and the choice of the actual rate of climb and number of boards per daylight will be governed by this factor.

When steam is used, the temperature can be controlled by the adjustment of pressure alone, but we use exclusively high-pressure hot water at about 195°C and 215 lb/in². This requires somewhat more elaborate control systems but, in our experience, the complication is more than compensated by the increased reliability and accuracy of control, lower maintenance costs and much reduced corrosion problems.

The method of control is shown in Fig. 8 and is as follows: The press platens *E* and the by-pass *D* form

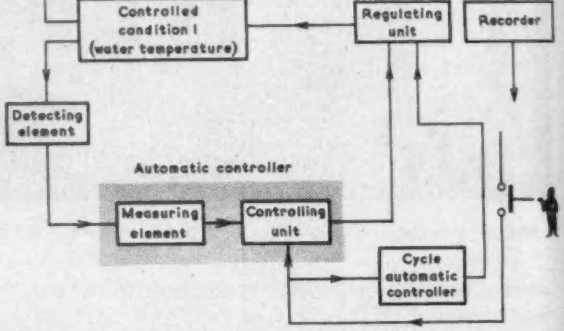
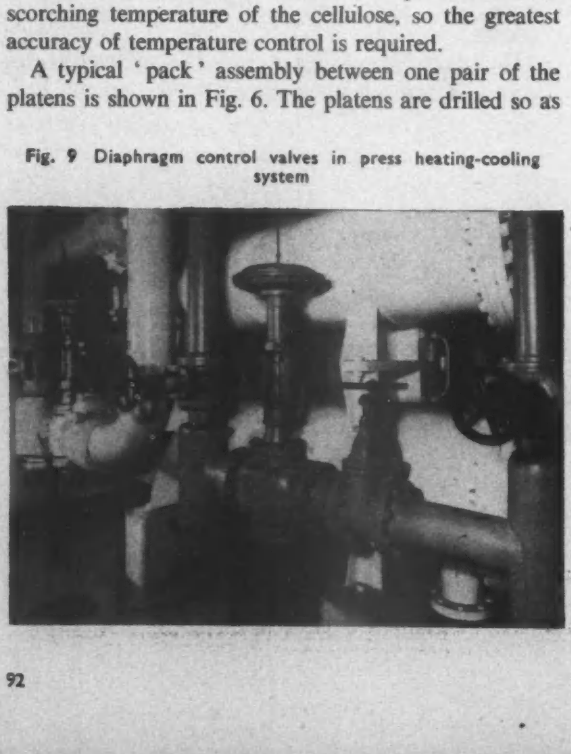


Fig. 10 Automatic temperature-control on press, monitored from remote manual station

Fig. 9 Diaphragm control valves in press heating-cooling system



a closed circuit around which the water in the system can be circulated by the pump *P* when the proportional-acting valve *B* is open and valve *A* is closed. When valve *A* is open and valve *B* is closed, the hot water from the boilers is allowed to pass directly through the platens (Fig. 9).

By having both valves air-operated from a common air line, and acting oppositely so that one is fully closed when the other is fully open, the ratio of fresh water from the boilers to recirculated water can be maintained at any level and thus the temperature automatically controlled.

At the end of the heating cycle, the platens are cooled by closing the *A* valve and admitting cooling water to the heat-exchanger loop *H*. As a result of this method, the whole boiler system operates on a closed circuit and very little make-up water is ever required.

The measuring element of the temperature controller should ideally be placed in the boards between the platens, since it is the temperature at this point which we wish to control. However, the heat insulation of the work and the heat capacity of the system are so great that it is quite impracticable to control the temperature in this way, and the point of measurement is in the water-line immediately before the platens.

Provided that constant conditions of press loading, ambient conditions, and temperature and pressure of the hot water from the boilers is maintained, then by controlling the temperature cycle of the heating medium in the press, a reproducible cycle in the work will be achieved. This formed the basis of our early control system, which utilized a Bristol Series-500 proportional controller together with a cycle sequence controller having a different cycle cam and timing disk for each different daylight loading or press cycle.

However, the large number of different cycles required on each press for varying thicknesses and grades of boards produced, together with the uncontrollable variables among press loads intended to be identical, rendered this system impracticable and did not give the required degree of control. The desired values on each press temperature-controller and cycle-controller had therefore to be adjusted manually, so that the desired time/temperature curve on the work could be obtained from a thermocouple placed in the work.

We have recently developed a system of remote control which enables us to have a total of twelve presses, of widely varying characteristics and functions, controlled by two men from a central console. The system used is shown diagrammatically in Fig. 10. In this system the desired value of the water temperature and the cycle phase condition are adjusted from the remote station by utilizing master and slave impulsing relays.

The master relay on the console enables the operator to set or adjust the water temperature at the press, or select the cycle phase, through the slave relay which operates a pair of cams, one for temperature and one for cycle phase, in a modified Bristol Series-500 two-case automatic temperature-controller and cycle automatic controller.

The effect of these adjustments on the work in the press is observed on a multi-point recording potentiometer from a thermocouple in a fixed position in the work. A high degree of accuracy can thus be obtained and cure cycles are reproducible to within $\pm 2°C$ in temperature and ± 2 min in time. Fig. 11 shows a typical water-temperature/work-temperature curve produced by this method (Fig. 12).

Finishing

The finishing operations consist of separation of the pairs of boards, inspection for surface faults, trimming, sanding of one or both surfaces and packing. There is considerable scope for transfer machines to eliminate manual handling between these stages, provided that the

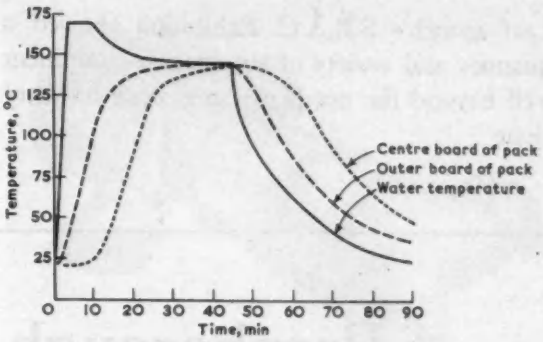


Fig. 11 Relationship of water temperature and work temperature in press

precision and sensitivity required to handle very large sheets of expensive and relatively fragile material can be developed.

QUALITY CONTROL

The whole question of process and quality control of laminates is extraordinarily interesting, but will not be discussed in detail in this article. The customer, very rightly, demands that every square inch of material that he buys shall be fully up to standard and consistent in its properties and appearance, since the failure of a piece of laminated plastics costing a fraction of a penny can cause serious damage under certain circumstances.

This consistency has to be achieved in spite of the fact that most of the raw materials, much of the process, and all of the products can only be controlled on a

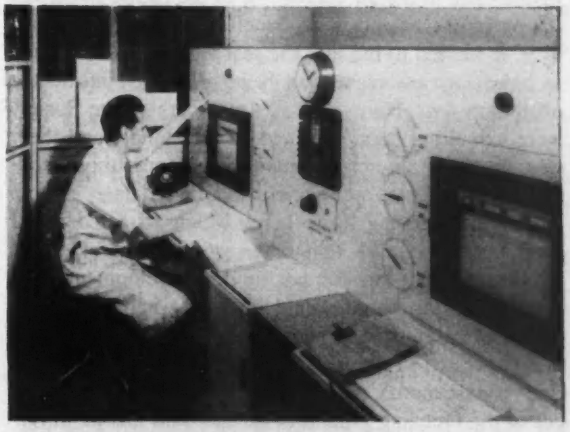
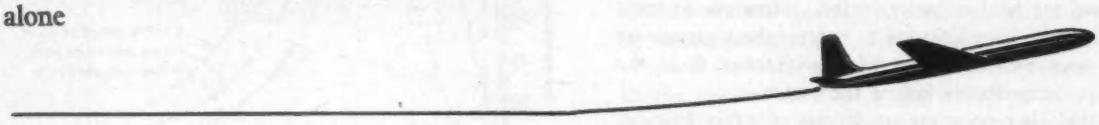


Fig. 12 Central station for press control

statistical basis in which the standard deviation is as important as the mean.

The overriding need is the means of reducing variation of all properties to the minimum at all stages of manufacture by the increasing use of more sophisticated methods of continuous measurement. So important is the need for the closest possible control that the laminates manufacturer will advisedly adopt the view that constancy is not merely a means to an end but, truly, an end in itself.

Last month's S.B.A.C. Exhibition showed a quantity and variety of automation equipment well beyond the needs of the aircraft industry alone



Farnborough *impressions*

by **M. JAMES, DIP.EL.HONS., M.BRIT.I.R.E.**
de Havilland Propellers Ltd

ANOTHER FARNBOROUGH SHOW HAS COME AND GONE, BUT not I think *just* another. On the one hand it was a coming of age, for this year The Society of British Aircraft Constructors held its 21st Display and Exhibition, and on the other hand we were able to see the first public demonstration of an aircraft performing the transition from jet-borne hovering to wing-borne forward flight. Thus a new and immensely important era opens up. With this exception the remainder of the aircraft on display and in the air conformed to the recipe as before; minor improvements here, small changes there. However, it seemed to me that the real vigour, initiative, and technical advancement was being displayed inside the exhibition tent. Here over 300 members of the Society were exhibiting their products on the stands, and there was much of interest, particularly among those concerned with parts, accessories, and materials.

Before discussing those items which attracted me, I am bound to remark that it seemed inconceivable that the few aircraft on display, under development, and on the drawing board, could provide a market for the wealth of equipment shown. The saving grace is I think well expressed in the words of Sir Roy Dobson, who in *Control* last month (p. 83) left us with the thought that out of the breeding ground of aircraft and missile development may come the equipment and ideas that will foster and advance automation systems in a much wider range of industry.

V.T.O.L. WAYS AND MEANS

One of the major reasons for producing a v.t.o.l. aircraft is to overcome the problems of the supersonic airliner where it is difficult to make a wing efficient at high speed and yet give sufficient lift at low speed to ensure that take-off and landing are no faster than with present-day aircraft. Dr Griffiths of Rolls-Royce proposed use of the wing for the high-speed case and a new form of lift, namely jet reaction, to deal with take-off and landing. Three interesting approaches could be seen at Farnborough, made by Short's, Bristol Siddeley, and Boulton Paul.*

Control for v.t.o.l.

Little could be gleaned of the problems of autopilot systems for v.t.o.l. aircraft apart from the Short S.C.1. They are undoubtedly complex and will make heavy demands on reliability engineering, and on reference elements such as gyroscopes, it was therefore of interest to learn that Sperry are devoting engineering effort to meet the requirements of two major aircraft companies working on v.t.o.l. machines. Furthermore, as v.t.o.l. aircraft are coming into being at a time when airspace, particularly over landing fields, is becoming progressively more crowded, this must surely lead to the wider use of blind-landing aids and the integrating of navigational systems with the aircraft autopilots.

Short S.C.1

The first transition flight was made with this aircraft on April 6, 1960, and demonstrated that the difficult problem of control had been overcome. The autostabilizer that is used has been developed by Short's Precision Engineering Division. A triplex system has been adopted to give the high degree of reliability which is essential for safe vertical ascent and descent. All three channels in this are continuously working, and each is capable of providing full control power. Should one channel fail it can be overpowered by the other two, and the control force obtained from the servo-motors will be unimpaired.

Autostabilization is provided about the pitch and roll axes, but control in yaw is left entirely to the pilot. Facility is given to the pilot to vary the basic control equation for the two channels independently in flight. The pilot has the choice of three equations.

'Servo-manual'	$M = as$
'Rate auto'	$M = as + b\dot{\phi}$
'Full auto'	$M = as + b(\dot{\phi} + c\phi)$

where M is the control movement, s the control column displacement, ϕ the aircraft attitude, $\dot{\phi}$ the rate of change of aircraft attitude, and a, b and c, are adjustable co-efficients.

Output signals from the amplifiers are fed to an electrohydraulic servo-motor for translation into control

* The second instalment of an article on the control of v.t.o.l. aircraft appears on p. 105 ff of this issue.—EDITOR.

forces that can be applied to the conventional control surfaces, and to the air-jet nozzle.

The stick signal (*as*) is obtained directly from potentiometer pick-off units at the base of the control column. In the case of 'Full auto' the aircraft rate and attitude signal is derived from an electric spring rate gyroscope.

The S.C.1 has five Rolls-Royce R.B.108 engines, each rated at 2010 lb thrust, or 8·1 lb thrust per lb weight. Four of these engines are mounted vertically in a central engine bay, and the fifth exhausts horizontally at the tail giving thrust for forward flight. After vertical take-off the four lifting engines are inclined backwards to give a forward thrust component, and before vertical landing they can be moved forward to give a braking thrust. All five engines have a compressor bleed supplying

Fig. 1 Short S.C.1. v.t.o.l. research aircraft in transition from hovering to forward flight

high-pressure air to a common duct which feeds air nozzles used for stability control in hovering flight. These control nozzles are at the wing-tips, nose and tail.

Bristol Siddeley B.S.53 engine

It was most interesting to see this alternative approach to the problem of obtaining lift-thrust for a v.t.o.l. aircraft. This high-ratio ducted-fan engine will power the Hawker P 1127 v.t.o.l. close-support fighter. The total thrust is directed roughly equally between that provided by fan air and that provided by exhaust gas. Each of these divisions may be, as in the Hawker P 1127, further subdivided by bifurcated ducts into equal parts, so that approximately a quarter of the total thrust is available at four points which can be conveniently disposed around the aircraft's centre of gravity. The inclination of the nozzles can be varied simultaneously from a directly-rearward direction to one in which they are facing slightly forward of the vertical if some reverse thrust is required. Nothing has yet been disclosed of the method of autostabilization, but it seems apparent that the transition from vertical to horizontal flight is smooth and uncomplicated, being effected simply by rotation of the nozzles.

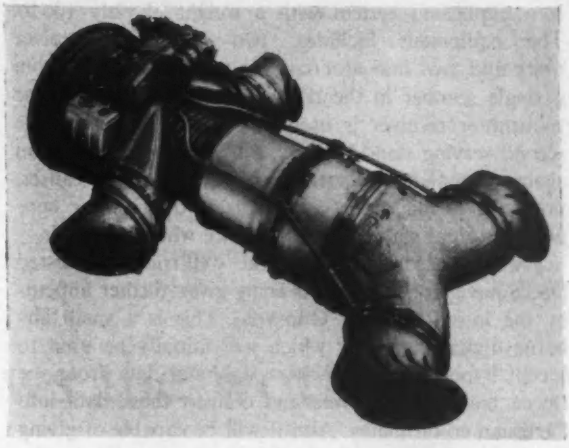


Fig 2 Bristol Siddeley B.S.53 lift/thrust ducted-fan engine with moveable jet nozzles to divide the thrust in any proportion between lift and propulsion

Boulton Paul ducted fan

Boulton Paul have examined several possible configurations of v.t.o.l. aircraft. One example is an aircraft using ducted-fan lifting engines. This airliner would be lifted by means of four banks of engines mounted at the wing-tips and on the nose-plane. The machine would be controlled by varying the thrusts of the various banks, thus avoiding the lift penalty which is associated with the use of bleed air.

NAVIGATION AND CONTROL IMPROVEMENTS

I was encouraged to see that the ideas developed by the R.A.E. at Bedford have been carried to an advanced stage in the Smiths B.L.E.U. Autoland system, which has been selected for the D.H.121. The B.E.A. specification called for full provision for easy adaptation to scheduled auto-landing, within the service life of the aircraft, to be made in the initial installation. Autoflare control is to be provided right from the start, together with full integration between the control of the automatic system and the revelant instrument displays. The initial installation will be at duplex level, but with provision for a later extension to triplex, that is to say three independent sub-channels working into a single controlling channel.

This principle of applying redundancy to the task of increasing reliability is also being shown by Elliott's auto-blind-landing system for the V.C.10. They are developing a duplicated system in which both channels are separately monitored by a further two channels. It will be interesting to observe how these rival systems compare in practice.*

Following the same theme of reliability through multiplexing, the new Ekco low-weight weather radar,

* A special article on this subject appears on p. 102 ff—EDITOR.

is a duplicated system with a weight of only 100 lb. The equipment includes, two transmitter/receiver units and two indicator/control units, operating from a single scanner in the nose of the aircraft. Only one transmitter/receiver is used for normal operation, the second serving stand-by duty. For maximum protection against complete system failure due to external causes, provision is made for connexion to dual power supplies and dual stabilization reference where available.

I was pleased to see that the well-tried and tested Decca navigator system was being given further impetus by the introduction of Omnitrac. This is a small airborne digital computer which will initially be used to accept hyperbolic-co-ordinate positional data from the Decca navigator receivers and convert these data into Cartesian co-ordinates. Also it will be capable of giving bearing and range information on any point in the coverage, to the highest accuracy of the Decca system. This equipment is a fine example of how airborne electronic units should be designed. It consists of a small magnetic memory, and some 300 logical elements using approximately 600 transistors and 800 diodes. Total volume is less than 1 ft³, weight 40 lb, and power consumption approximately 35 W.

It seems inevitable to me that completely automatic air-traffic scheduling, navigation control, and landing must come over the next decade, but much can be done to improve the existing methods. I was therefore glad to find that S.T. and C. have produced a television-style triangulation display equipment, type P.V.T.2. This represents a new stage in the development of the current standard P.V.T.1 triangulation equipment, which employs back-projection on a 5-ft-square map screen. The new display system offers two main advantages over that of the P.V.T.1. First, it provides an economical means by which each user of the system can have his own display on a television monitor. Secondly, it allows superimposition of d.f. triangulation fixes at will on television-style radar displays, with the possibility of instant removal of the d.f. information without afterglow, to clear the display for maximum radar readability. The primary function of the equipment will be to identify and locate aircraft entering or flying through controlled airspace, using only the signals radiated by the aircraft in the course of ordinary communication with the control centre.

Before leaving the realm of navigation and control, I must mention the de Havilland fuel-control system, which is now in quantity production for the Gnome engine, and is the world's first fully-automatic electric fuel-control for helicopters. The system combines a gas-turbine-engine fuel-control, which provides an output to drive a fuel throttle, with a full-authority rotor-speed governor. The latter's transient response characteristics can be made compatible with any helicopter rotor and transmission system to provide stable and rapid control. The governor controls the engine fuel flow to provide the power necessary to keep rotor-speed constant under all conditions of flight without any action on the part of the pilot. The most important feature of the engine control is that gas temperature has been chosen as the principal control parameter to ensure the best operating conditions and the maximum life between overhauls for the hot parts of the engine.

THE SEARCH FOR PERFORMANCE

The world of aircraft and missiles is demanding upon an engineer. Always the cry is for better performance, reduced size and weight, more reliability, and lower cost. In looking for improvements in performance I found many interesting examples, of which I can mention but a few.

Gyroscopes have again improved; quoted drift rates and life are now beyond the wildest expectations of but a few years ago. To give an idea of what can be achieved, advance information on drift rate for the miniature integrating gyroscope GG 49 D is that the r.m.s. variation during one warm-up (laboratory-type environment, fixed orientation) is 0·1°/h per g and 0·05°/h maximum.

The modern counterpart of Hero's wheel (now 2000 years old) was shown by the Precision Engineering Division of Short Brothers and Harland, and is the free gyroscope designed for the Seacat ship-to-air guided missile to provide roll stabilization. The gyroscope is started by firing a cordite charge within the rotor. On starting, the firing leads contained in a hypodermic needle are swung out of the way and a speed of 36,000 rev/min is achieved in 0·1 sec, giving a one-minute run with less than 3½°/min drift. All-up weight is 7½ oz.

The search for high-temperature performance was well demonstrated by Vactric. With the increased use of control systems on modern high-speed aircraft, precision electromechanical devices are required to operate continuously at higher and higher temperatures. The demonstration showed a simple positional servo-mechanism incorporating a special high-temperature International-Frame-Size-11 resolver for positioning control, working in an ambient temperature of 200°C and driving a variable load with a maximum torque of 30 lb in. Units can also include a d.c. motor which can be brought into operation in the event of a.c. supply failure. A motor similar to that demonstrated has been developed for a Bristol Siddeley jet engine.

While on the subject of performance, I may say that I was impressed by the high-frequency response so convincingly demonstrated by the Dowty Moog servo-valve connected as an element in a hydraulic 'hi-fi' system. The demonstration rig consisted of a tape recorder feeding a d.c. servo-amplifier followed by a Dowty Moog series-21 servo-valve. This controlled the hydraulic drive to a jack connected via a spindle to the diaphragm of a loud-speaker assembly. Positional feedback was incorporated. The 'hydraulic' loud-speaker transmitted information with acceptable speech quality. This was followed by spot frequencies in the band 200–1100 c/s. The finale, quite improbably, was a passage of music—not Handel's *Water Music* either!

Stockholm shows the world

Principal highlight at the 5th I. & M. Conference and Exhibition was a Swedish digital computer. Its fast, time-sharing operation opens up a new approach to process control

by **E. H. WERNINCK, ASSOC.I.E.E.**
Evershed & Vignoles Ltd

THE COMMERCIAL EXHIBITION WHICH OCCUPIED Osterman's marble halls and opened on September 10 was sponsored by the Swedish Instruments Suppliers Association. There were sixty exhibitors, but as many of them represented six or more foreign firms, close on 400 manufacturers from many countries had their products on show. In addition to measuring devices and transducers there were many control elements, and components finding application in almost every branch of engineering. Medical and analytical instruments were present in customary profusion.

TWO HIGHLIGHTS

A British section, occupying about one third of the total available floor space, was organized by the U.K. Atomic Energy Authority in conjunction with the Nuclear Energy Trades Association Conference. The centre of this section was the Authority's well-designed stand showing instruments related to reactor control and development.

The other highlight of the exhibition was remarkable because of the *small* amount of space it occupied. Though miniaturization is hardly news these days, the Saab Electronics D2 digital computer is a noteworthy achievement of the Swedish Aircraft Company. Designed with emphasis on speed, compactness and reliability, it offers—together with a reversible digital-to-analogue converter—a new approach to process control, permitting several programs to be run in parallel.

THE CONFERENCE

The conference, which took place at the Royal Institute of Technology, was as in previous years organized by the Royal Swedish Academy of Engineering Sciences and the Swedish Association of Technical Physicists.

Over 750 delegates gathered from twenty countries, and the program consisted of some 120 lectures and many visits and social functions. The State Council of Technical Research assisted in the scientific exhibition at the Institute of Technology, showing examples of developments and experiments carried out in Government research institutes and universities. In this scientific exhibition the U.K.A.E.A. also had a very large stake, occupying a whole room with examples of instruments and techniques developed by the Authority's various establishments.

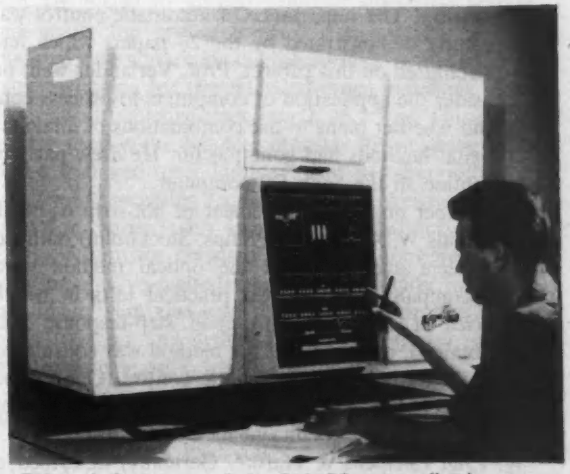


Fig. 1 A forerunner of the Saab D2, externally the same

THE MORE INTERESTING PAPERS

The conference opened with a short speech by the Conference President, Prof. Gregory Ljungberg, who drew attention to the fundamental importance of instruments and measurement—a point later taken up by Prof. Verlander. Human progress, said Professor Verlander, was largely based on the arts and sciences,

Whereas the arts depended on inspiration, intuition and dexterity, the sciences relied on logical theory and its gradual perfection by experiment. The link between theory and experiment was of course the instrument. The conference had therefore an important part to play in furthering the development of better and more

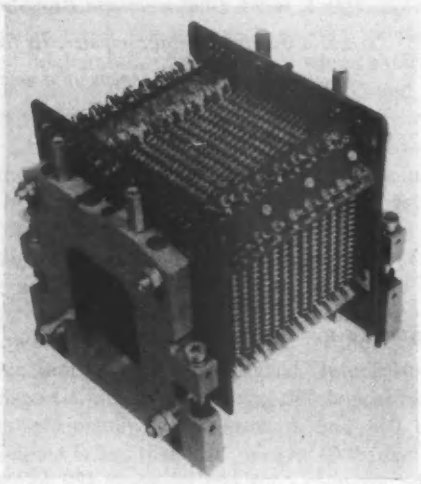


Fig. 2 Saab ferrite-core memory. There are twenty layers containing 1024 cores plus driving circuits for read-out and writing

accurate instruments, required in particular by the control industry. The importance of automatic control was very clearly demonstrated by the 26 papers which had been submitted on this subject. Prof. Verlander went on to consider the application of computers to process control, and whether plans to use combinations of analogue and digital methods had gone too far. He drew particular attention to the Saab D2 computer.

In a paper on the measurement of hot-strip width in rolling mills W. Ask (A. B. Philips, Stockholm) outlined the problem and described the optical method used by his company. He reported practical tests in which accuracies of 1/10 mm with good step-response had been obtained, and said that the method was considered to offer possibilities for automatic control. One of the factors precluding greater accuracy was the absence of reliable temperature-coefficient measurements.

W. Engl (Siemens & Halske, Germany) described a method of transmitting information from strain-gauge load cells. The method uses a transformer fed with 311 c/s as reference, and the pulses setting up the balance voltage are transmitted over a microwave link.

Recent developments in pneumatic, electropneumatic and electrohydraulic control was discussed by M. V. Broïda (Société Française des Regulateurs A.R.C.A., Paris). In his paper M. Broïda described the introduction of integral and derivative control components after the transformation of the electrical signals into proportional pressure-signals and the advantages of this method where large time constants are involved.

W. Troost (N.V. Philips, Holland) described a miniature potentiometric recorder. This he felt would be particularly useful in chemical plants and oil refineries where miniaturization, stability and reliability were of prime importance. A special transistorized 'squarved' amplifier had been developed to obtain a higher input-impedance than was normal with transistors, and a discrimination of 1 μV had been achieved. The reference voltage was obtained from a bridge circuit one arm of which consisted of a temperature-compensated Zener diode. A long-term stability of better than 0·1% is claimed for this circuit.

In his paper B. Jierwertz described the construction and principles of the very fast Saab D2 computer. He gave details of its capacity and mentioned its ability to sample at 100 c/s. An input unit had been designed as an integral part of the computer and was capable not only of digital-to-analogue and analogue-to-digital conversions, but of matching a variety of input data. Particular care had been taken in circuit design, and all components had been subjected to searching and lengthy environmental tests. To speed construction a few standard logic circuits were built up into modules for connexion to the unit printed-circuit cards. To obtain high reliability all connexions were soldered, and though the computer would contain 6000 transistors and 3500 diodes, an extremely high reliability-factor had been computed from the component and sub-unit test data so far available. The computer weighs around 500 lb and consumes only about 300 W.

WILL IT BE WORTH HAVING ANOTHER ?

Many of the lectures suffered by being restricted to twenty minutes; this was to allow ten minutes for discussion. Mr Helge von Koch, the Secretary-General of the organizing committee, told me that the committee had had the very difficult task of either rejecting some of the excellent papers submitted, or of allocating to them what was appreciated to be rather a short time. An extension of the conference was also considered impractical as companies sending representatives had indicated that their staff could not be spared for long. No plans were at present being made for another conference in Stockholm, though the committee had of course discussed it. They felt that, before even tentative dates were put forward, the overall picture of conferences would have to be studied.

THE COMMERCIAL EXHIBITION

This in general was typical of continental exhibitions, e.g. those held in Utrecht and Basle. All the well-known names were there, and though the numbers of exhibits from Britain, America and Germany did not differ greatly, the impressions as usual were of a predominance of American equipment and of effective displays from Germany. The U.K.A.E.A.'s contribution did much towards minimizing these impressions.

The number of control equipments, some working in conjunction with Swedish plant, was particularly noticeable. A British-made controller was shown together with a small electronic unit acting as a plant simulator.

Of one fact there was no doubt; Sweden's contribution, particularly considering her size, was impressive.

Saab

Of the Swedish Saab company's 1600 engineers and technicians 400 are working in the electronics field. The latest achievements of those engineers were illustrated by some of the equipment the company had brought to the exhibition. The centre piece was the D2 computer, fully transistorized for compactness and low heat losses, and designed with emphasis on speed and reliability. Because of its high speed it has a large computing capacity, and using the built-in program-interruption feature it can run several programs in parallel. Should an emergency condition occur on any of the processes controlled, the computer can be made to interrupt the normal sequence and deal with the emergency. The principle of operation is based on parallel-operated binary numbers and one-address instructions. Two ferrite-core stores, one for orders and the other for data, have capacities of 4096 and 2048 words comprising 20 bits respectively.

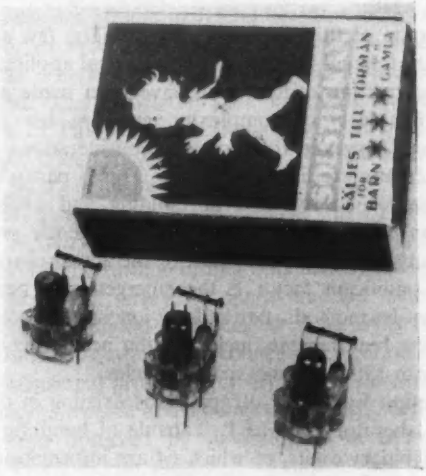


Fig. 3 Saab pre-assembled logic units

Two magnetic-tape memory units (' Saraband '), each storing over a million 20-bit words can be added. The computer is built of printed-circuit panels on which are mounted pre-assembled logic units. Up to 64 channels are available for digital and analogue inputs and outputs. The accuracy claimed for the built-in converter is 0·1%, and it is a special feature of this computer that all input and output channels are directly addressable.

A reversible analogue-to-digital converter with analogue channel selector, which was designed as a direct matching unit for digital computers, was also shown. The technical specification is rather a lengthy one, and it is hoped that the accuracies quoted in the preliminary specification will give some indication of its capabilities. For analogue to eleven-binary-digit conversion, for an input range of $\pm$ 10 V, the accuracy is stated as $\pm$ 5 mV or half the least significant digit. In the digital-to-analogue the accuracy is within 0·05% of full scale.

The company also manufacture a range of transducers and eventually hope to market their circuit modules, printed-circuit boards and memory units.

Facit

Facit, the electronics division of the famous Avitaberg company for office machines, showed a model of their E.D.B. computer centre. This is claimed to be one of the largest organizations of its kind in Europe and has been operating since 1957. Their latest developments, a new electronic tape-reader (ETR 500) and high-speed tape-punch (ETP 150), both transistorized, were also on show. The speed of the reader is 500 line/sec and it is capable of stopping after every character. The punch can produce 150 line/sec and can handle 5-, 6-, 7- or 8-channel tape with 10 line/in. Also on show was a completely new type of magnetic-tape memory, the ECM 64. It differs radically from existing external memories with direct access, and is described by the company as a ' carousel ' memory.

Elenik

An extensive range of weighing equipment was shown by the Stockholm firm Elenik. This was designed and manufactured by them and consisted of: (1) A complete electronic weighing system, with digital read-out and printing facilities, made up of a weighing bridge containing strain-gauge load cells, a control console with key-board to initiate printing, automatic tearing, and finally the printer itself. There was also a wall-mounted case containing the measuring circuit, and automatic switching for the extended-range indicator, which thus had an effective scale length of 2·5 m. This equipment is used in the cellulose industry for weighing bales, in the iron and steel industry, and in other industries with similar weighing requirements. (2) Weighing equipment for cranes, with large digital read-out. (3) The Eledin system for constant feeding by conveyor, incorporating a servo-regulator and preset counter for batching. There were also load cells having capacities of 100 kg to 100 tons, and hydrostatic transducers for measuring pressure, specific weight and flow.

A.S.E.A.

The Pressductor load cell was shown by A.S.E.A. In this the magneto-elastic properties of iron laminations are exploited to produce a unit with high output and low internal impedance. The output is normally large enough to feed an indicating instrument or relay directly. The units are extremely robust, require no maintenance, and because of their relatively small dimensions are particularly suitable for the measurement of screw-down forces in rolling mills. Particular attention is paid to mechanical design, and among typical constructions shown was a very simple flat unit for very large loads. For measurements of torque without slip-rings there was the Torductor using the same principle, and a special form of journal box was shown with a built-in Torductor.

There was a good deal for the theoretically minded control engineer at this excellently organized international meeting

Information theory

—*the fourth London Symposium*

by **A. M. ANDREW**
National Physical Laboratory

THE FOURTH LONDON SYMPOSIUM ON INFORMATION Theory, held during the week 29 August to 1 September at the Royal Institution, maintained the high standard set by the previous meetings in 1950, 1952 and 1955. A valuable set of papers, 36 in number, was presented, and the discussion, to quote Professor Cherry's closing remarks, was 'fluent, violent and heretical'.

Coding theory

Four papers were concerned with error-correcting codes. In the practical case of randomly occurring noise, the channel capacity for reliable transmission becomes greater with increasing length of the groups of symbols handled by the coding procedure. For very long groups the complexity of the receiving apparatus (or amount of computer time to decode each group) is likely to be prohibitive, and the question of feasibility of the terminal apparatus received much attention.

N. M. Abramson (Stanford University, California), in his paper *Error Correcting Codes from Linear Sequential Circuits*, as well as J. E. Meggitt (British I.B.M.) in discussion, described types of error-correcting codes, which for moderate group lengths, can be achieved with very simple terminal apparatus consisting essentially of a delay line (or stepping register) with a small number of arithmetic elements coupled to it. However, their technique does not provide an immediate answer to the problem for longer groups.

J. M. Wozencraft and M. Horstein (M.I.T.) in their paper *Coding for Two-Way Channels* described a method in which the average time taken to decode a group of n symbols does not rise unduly steeply with increasing n. However, the time taken to decode a group is not constant, and depends on the errors present. The method could be used most profitably when two-way transmission was possible, so that the receiver could request a re-transmission of a group which was taking a long time to decode. Previous work on error-correcting codes has generally ignored the possibility of two-way communication, but the current emphasis on practical feasibility of terminal apparatus suggests it may be well worth while.

In spite of this emphasis on feasibility, few speakers described actual hardware. The practical applications of error-correcting codes which have been made are at a very low level of complexity, and are few and far between. However, the economic considerations governing their use are likely to change. This is partly because a reduction in the cost of building and maintaining terminal equipment can be more confidently predicted than any reduction in the cost of the actual channels. A more significant factor is the emergence of new communication methods, particularly ionospheric scattering, and new requirements including the need to communicate with satellites and space vehicles.

Mention was made of apparatus existing in the Lincoln Laboratory of M.I.T., capable of handling blocks of 128 binary digits, of which 64 are information digits and 64 check digits. Seven errors can be corrected. The fact that this equipment is not unduly bulky does not appear to be due to any special feature of the system of coding, but rather to the effectiveness of modern techniques of miniaturization.

Biological flavour

As in the previous symposia, a number of the papers had a biological flavour. The present writer put forward some ideas, in his paper *A Self-Optimizing System of Coding*, which are rather distantly analogous to what may happen in a sense-organ. An immediate application of the ideas was to provide a means of recoding messages consisting of binary digits so as to reduce their length, in the case where there are reasonably long stretches of message having either a high or a low proportion of one-digits. A. E. Laemmel (Brooklyn Polytechnic) described, in discussion, some simpler ways of achieving this particular result.

Papers by J. A. Leonard (Medical Research Council,

Cambridge) and E. R. F. W. Crossman (Reading University) applied information theory to the results of reaction-time experiments and experiments on memory, respectively. Crossman's theory accounted rather neatly for a large amount of experimental data. It depended on the principle of considering separately the 'what information' and 'order information' of a memorized message (the 'what information' being a list of the symbols in the message, and the 'order information' referring to their order of occurrence). Other papers dealt with hesitation in speech, storage of visual information, observation by human observers of signals in noise, binocular depth perception, sound localization, and neural discharge patterns.

An improved version of Grey Walter's 'tortoise' was demonstrated by A. J. Angyan, H. Kretz and H. Zemanek as *A Model for Neurophysiological Functions*. Many of the audience felt, as Professor Zemanek drew elaborate block schematic diagrams on the blackboard, that Grey Walter's principle of 'parsimony' had hardly been observed in the design of this device. Unfortunately Dr Angyan, who is the neurophysiologist in the group, was not present to defend his ideas in this respect, but Warren McCulloch (M.I.T.) spoke on his behalf to say that the principle of parsimony had indeed been observed. The model, he said, exhibited all the phenomena of Pavlovian conditioning, and in spite of the apparent complexity its behaviour was basically determined by a circuit having only four valves.

B. G. Farley and W. A. Clarke (M.I.T.) in their paper *Activity in Networks of Neuron-Like Elements* described some further results obtained by simulating a two-dimensional array of interconnected neuron-like elements on a digital computer. With an array of about a thousand cells, whose interconnexions were specified by two-dimensional probability distributions, they were able to observe waves of activity and other phenomena which have been observed by physiologists in living brain tissue. However, no suggeston was made that the simulated networks had, or could, organize themselves to perform any useful function.

Networks as learning systems

M. Minsky and O. G. Selfridge (M.I.T.) in their paper *Learning in Random Nets* poured quite a lot of cold water on the idea that a large randomly-connected net of simple elements should be expected to organize itself to show behaviour which could be termed 'intelligent'. They discussed various features of learning models, and conclude that: 'A random net may be a useful technique for small local jobs like—(1) performing correlations or averages among inputs, (2) clasifying inputs by assigning connexions, or (3) optimizing categorization by improving connexions and weights of connexions. One should not expect from a random net more complex behaviour than this without some adequate theory to suggest and propose it'.

Selfridge further supported these conclusions by stating that a detailed examination of the brain showed that no part of it had the appearance of a random net. It was suggested that some form of hierarchial organization, or program, is needed for any interesting form of self-organization. These workers consider that it is by attempting to produce advanced forms of artificial intelligence, such as chess-playing by machine, that progress will be made in understanding human thought processes. Simpler problems, such as the playing of noughts and crosses, can readily be solved in many ways which are trivial from the point of view of the study of intelligence. Minsky says he beats his students over the head if necessary, to dissuade them from making more and more machines to play noughts and crosses!

The critical assessment of possibilities for learning in random nets is timely in view of the publicity given by F. Rosenblatt to his 'perceptrons'. These were also mentioned by S. Papert (N.P.L.) in his paper *Mathematical Models of Perceptual Learning*.' A simple perceptron-arrangement consisting of sensory, association and response units, is considered. Each association unit is connected to several sensory units and stores a quantity which is modified in the course of training the perceptron. The device can be trained to classify a set of input patterns into subsets, the training procedure being to present the different patterns along with an indication of the subset to which each belongs. By an elegant piece of mathematics (which apparently conflicts with Rosenblatt's work in some respects), Papert has shown that the number of association units needed by the machine to learn a particular task of classification is much smaller than previous estimates have suggested. However, his treatment does not show how random nets can do anything more than classify patterns already presented; it does not lead to generalization of patterns, and the conclusions of Minsky and Selfridge are unaffected.

Other learning machines

The *Self-Optimizing Non-Linear Filter, Predictor and Simulator* described by D. Gabor, W. P. L. Wilby and R. Woodcock (Imperial College) is a most important development, and its construction is now complete. Its operating principles will not be described here as they have been published previously.

Other papers with a bearing on learning mechanisms dealt with adaptive wave-form recognition, task simplification for learning devices, and hypothesis formation by computer. The property of hypothesis-formation was embodied in a program which learned to make a correct classification of a set of binary inputs by a more economical process than listing appropriate responses for all possible binary combinations.

The whole symposium was extremely stimulating. The excellence of Professor Cherry's organization of it is illustrated by the triviality of my one suggestion for improvement. At the fifth symposium could we please have a source of drinking water so that our American friends can satisfy their addiction without having to raid the carafe provided for the speaker?

TWO APPROACHES:
Elliott's monitored-duplicated for the V.C.10
Smiths' multiplex for the D.H.121

Automatic landing and reliability

by **L. A. STOCKMAN**
Deputy Editor, Control

THERE IS LITTLE DOUBT THAT THE CIVIL AIR TRANSPORT of the next generation will be fitted with automatic equipment capable of landing the aircraft at suitable aerodromes under any conditions of visibility. The pilot will not intervene but will merely monitor the landing (although there are some who view even this minor degree of passive participation with misgivings). The pilot should of course be ready to take over from the automatic system if it fails, but as any automatic device which is likely to fail more than once in ten million operations is considered to be quite useless as a blind-landing control, the pilot—like the nuclear deterrent—must never be used.

For all practical purposes an automatic landing system must never fail. Consider the effect if a catastrophe is ever laid at the door of an automatic landing system: automatics would be discarded completely for at least ten years and pilots would continue to grope their way earthward using visually-obtained instrument information. It may be illogical, but there seems to be a greater willingness to accept human error than machine error, even if the latter is the smaller.

All this means that an automatic landing system is expected to be vastly more reliable than a pilot-operated system. The Air Registration Board has suggested that the overall risk of a fatal accident should not be greater than 1×10^{-7} and that, if possible, 1×10^{-8} should be the design aim; even lesser risk-figures have been bandied about.

The B.L.E.U. system

The Autoland automatic landing system, developed by the R.A.E.'s Blind Landing Experimental Unit at Bedford, has been highly successful, and some thousands

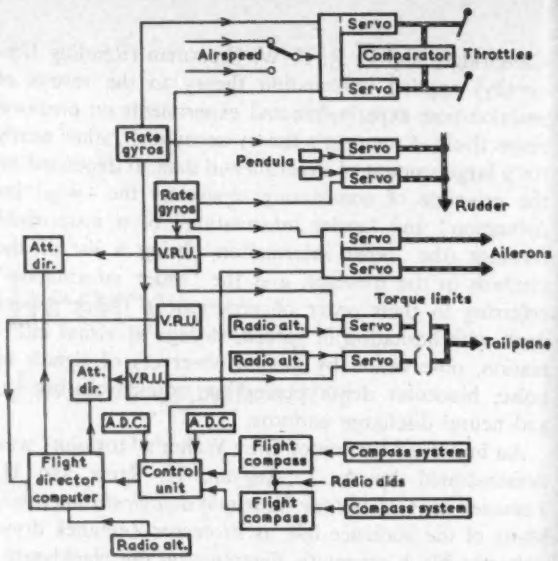
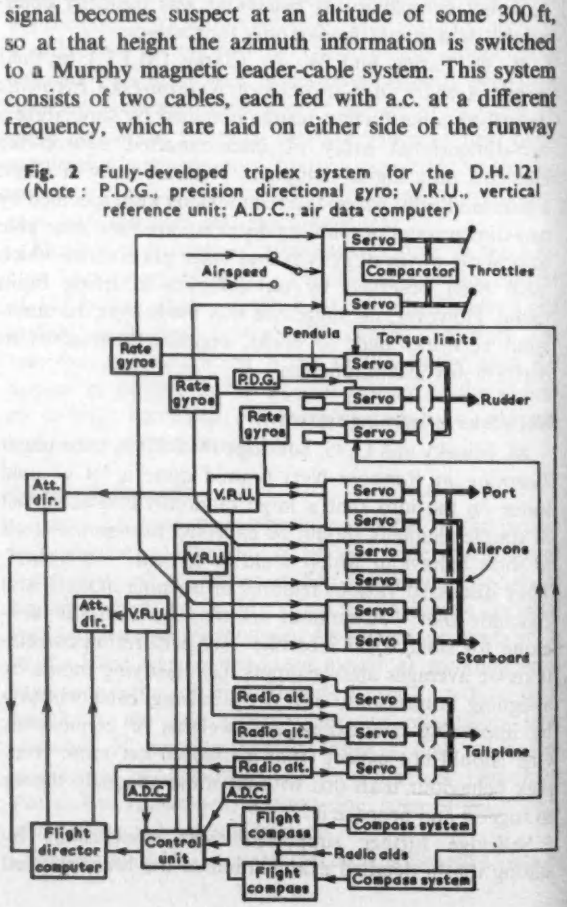


Fig. 1 The Smiths duplex system for the D.H. 121 Trident aircraft. The pilot will monitor its operation with the aid of the para-visual director

of fully-automatic landings have been made. Glide-path and azimuth information from a Pye instrument landing system (i.l.s.) is fed into a Smiths S.E.P. 4 autopilot which operates the aircraft control system. Airspeed during the approach and flare-out is regulated by a Smiths automatic throttle control. The i.l.s. azimuth signal becomes suspect at an altitude of some 300 ft, so at that height the azimuth information is switched to a Murphy magnetic leader-cable system. This system consists of two cables, each fed with a.c. at a different frequency, which are laid on either side of the runway

Fig. 2 Fully-developed triplex system for the D.H. 121 (Note: P.D.G., precision directional gyro; V.R.U., vertical reference unit; A.D.C., air data computer)



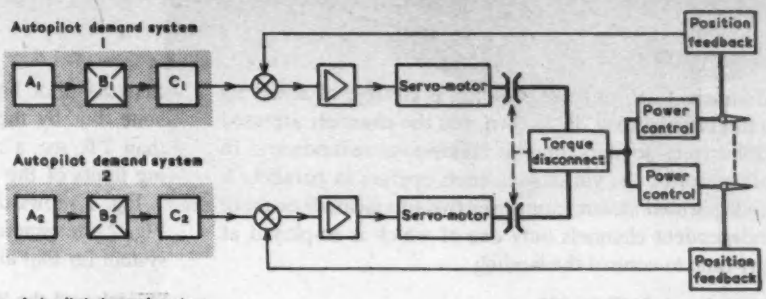


Fig. 3 A fully-duplicated single-channel autopilot control system. Here, failure of either sub-channel is caused to disconnect all automatic control

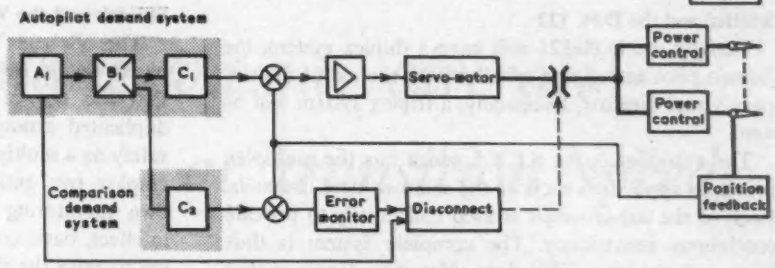


Fig. 4. The Elliott approach is based on the comparison-monitor technique. This arrangement, although simpler than that of Fig. 3, is understood to provide the same level of reliability. Note that one servo-motor, A_2 and B_2 in Fig. 3, are eliminated in Fig. 4, although C_2 remains

centre-line and extend about 5000 ft ahead of the threshold and along the runway for as far as azimuth guidance is considered necessary. The magnetic fields from these cables are detected in the aircraft, and their values are compared to give azimuth information with respect to the centre-line of the runway.

Below about 100 ft, the i.l.s. glide-path information becomes unusable in certain installations, so this is switched out automatically by a radio altimeter. The aircraft, however, continues to hold to the attitude it has adopted until about 60 ft above the threshold. The flare-out from 60 ft to touch-down is controlled by a Standard-Telephones radio-altimeter. This controls pitch attitude to give a rate of descent that is proportional to height, and so makes for a smooth flare-out. At about 15–20 ft, the final automatic sequence occurs: the wings are levelled and rudder is applied to remove any drift due to cross wind, so that the aircraft touches down close to, and aligned with, the runway centre-line.

This system, or something very much like it, is used by the R.A.F., and there is little doubt that it is a militarily satisfactory fully-automatic method of landing.

Problems of azimuth guidance

Considered for civil use, however, the Autoland system presents some problems. For example, the leader-cable method of providing azimuth guidance is rather involved. It entails laying two cables over 5000 ft long before the runway threshold, and this is neither desirable nor even possible in certain of the under-developed countries, or where aerodromes are near the sea. Apart from such practical difficulties, the very inflexibility of the scheme makes it unamenable to the sort of design approach which one expects for a modern system.

At one time it was thought that the azimuth guidance from the i.l.s. could be improved, so that a need for leader cables would be avoided, and, in fact, fully-automatic landings have been made using i.l.s. alone. Recently Standard Telephones & Cables produced a new i.l.s. which many thought was sufficiently accurate in azimuth to overcome the problem. S.T. & C. themselves, however, do not claim their i.l.s. to be a substitute for leader cables, because of difficulties which could arise when one aircraft is landing and a second aircraft is overflying the runway.

Elliott Brothers are working with B.L.E.U. on the development of a microwave beacon system for azimuth guidance. This provides a guidance path similar to that from leader cables, and consists of two small transmitters and aerial systems located on either side of the runway near to the touch-down point. They hope to use this microwave azimuth guidance system on automatic landings by the end of the year.

Reliability

The major problem for civil use is, of course, that of reliability. The probability of an incident during the landing manoeuvre when using the B.L.E.U. system is thought to be about 4×10^{-5}. With a human pilot, the figure might be 1×10^{-5}. It has been inferred that an automatic landing system should have a malfunction probability better than 1×10^{-7}—the design aim is 1×10^{-8}.

If it is assumed that all ground and airborne equipment must operate satisfactorily for a safe landing, and that a passive (or harmless) failure leading to a safe manual landing is not acceptable, a 'mean time between failures' of at least 80,000 hours would be required to cover a thirty-second landing period. This is obviously impracticable, and it follows that any item of airborne equipment which is not substantially better than this would need to have stand-by equipment in parallel.

There are at present two systems for obtaining the required high level of reliability: Smiths, who are responsible for the flight control of the de Havilland D.H. 121 Trident jet airliner, are developing a multiplex (duplex at first) arrangement; Elliott Brothers, who have a similar responsibility for the Vickers V.C.10, are working on a duplicated system with separate monitoring for each channel.

The terms *multiplex* and *multiplicated* are used to describe the Smiths and Elliott systems respectively. A multiplex system comprises two (it is then called 'duplex') or more independent information and control

channels. Each of these channels is capable of achieving automatic landing on its own, but the channels are used collectively so that there is continuous redundancy. In other words, the various channels operate in parallel. A multiplicated system comprises two (duplicated) or more independent channels only one of which is employed at any time to control the landing.

Smiths' and the D.H. 121

Initially the D.H. 121 will have a duplex system, the human pilot acting as a monitor with the aid of Smiths' para-visual director. Eventually, a triplex system will be used.

The autopilot is the S.E.P.5 which has the multiplex principle applied to each of the main control channels. Each of the sub-channels is used collectively to provide continuous redundancy. The complete system is thus in use all the time. This does offer the advantage that reversion after a failure is accomplished by switching out a faulty sub-channel, rather than by switching over to an alternative channel which was not previously in full operation. A triplex arrangement will revert to duplex operation if a malfunction occurs in one sub-channel; if a further malfunction occurs, both remaining sub-channels will disengage without disturbing the flight path of the aircraft.

It is, however, possible to arrange for simplex operation on failure of one sub-channel of a duplex system, if the aircraft can be safeguarded by conventional means—presumably the pilot would monitor the landing with the aid of the para-visual director.

In the event of an autopilot failure above 200 ft, the pilot should be able to overshoot, or to regain full manual control in time to land the aircraft himself. A failure below 200 ft will, with a duplex system, still leave the aircraft in trim, and the para-visual director will both give a definite indication of failure and act as a stand-by flight director. If such a failure should occur at the beginning of the flare out, it is assumed that the pilot can intervene within two seconds to re-establish control before touch-down. At a later stage, he will have less time, but the aircraft's rate of descent will be less. For example, a failure 30 ft above the runway means that the pilot has only five seconds in which to intervene, but by then the rate of descent should be lower than 7 ft/sec, a rate understood to be within the stressing limits of the undercarriage.

Fig. 1 shows the duplex system for the D.H. 121, and Fig. 2 the general nature of the fully-developed triplex system for that aircraft.

Elliott's and the V.C.10

The Vickers V.C.10 will have a duplicated system based on the Bendix PB 20 autopilot. Elliott's consider that the use of monitoring techniques enables their duplicated arrangement to provide the same degree of safety as a multiple-channel system. In practice, Elliott's employ two entirely separate channels, each with its own monitoring arrangements, these monitors being, in effect, basic control channels themselves and so tending to raise the duplicated system towards a quadruplicated arrangement.

Fig. 3 shows a fully-duplicated arrangement, and Fig. 4 a single-channel system with a comparison monitor. Both are claimed to offer the same level of reliability, but the design of Fig. 4 has considerably less equipment than that of Fig. 3. As the two servo-motors of Fig. 3 are not used independently, one only is used in Fig. 4, and the second autopilot-demand system of Fig. 3 becomes a comparison demand system in Fig. 4. Furthermore, certain equivalent elements of high reliability, or elements which can be made to give an absolute indication of failure, have been dispensed with. For example, A_1 is of such a nature that failure can be positively indicated, and B_1, is a mechanical device of high reliability, but the failure of C_1 can be positively detected only by comparison with a similar unit. Thus in Fig. 4, A_2 and B_2 have been eliminated, but C_2 remains.

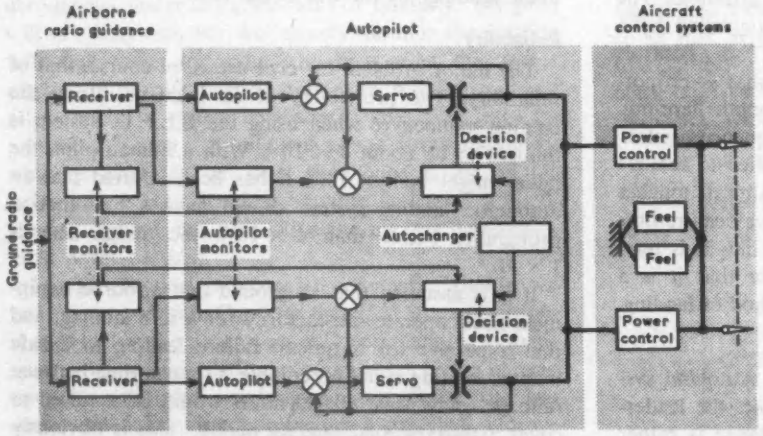


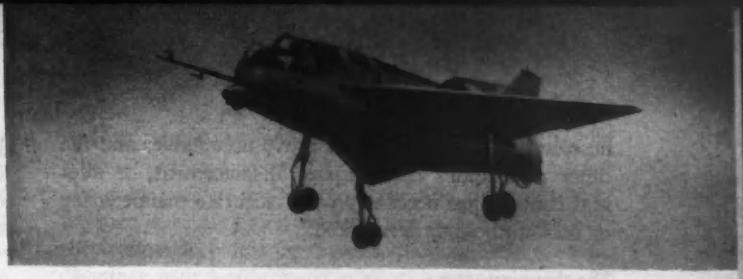
Fig. 5 Much simplified diagram of one control axis of the Elliott monitored-duplicated system for the Vickers V.C.10. In this duplicated arrangement, disconnexion of an operating sub-channel automatically initiates change-over to the stand-by sub-channel. Note that each sub-channel has its own monitor sub-channel

Fig. 5 shows the basic airborne equipment for one control axis of the Elliott monitored-duplicated system. The two channels are engaged alternatively and not simultaneously, and each is monitored by its own comparison monitor.

Acknowledgements

Thanks are due to Elliott Brothers (London) Ltd. and Smiths Aircraft Instruments for help in preparing this article.

PART 2



Controlling v.t.o.l. aircraft at transition speeds

by **JAMES J. FOODY**, M.SC., A.F.R.AE.S.
Short Brothers & Harland Ltd

Last month, in Part 1 of this article, we discussed the problems of lateral, longitudinal, and hovering stability.

STABILITY AUGMENTATION

There has been—and continues to be—considerable discussion on whether or not stability augmentation is necessary in the transition speed-range, and more specifically in hovering. The foregoing arguments show that, in the Dutch roll mode, instability occurs for even small speed-reductions from conventional approach speed. It is fairly certain that whilst this instability may be delayed it cannot be avoided. On the other hand, in hovering the aircraft will be at best neutrally stable, so that we can state without further analysis that an aircraft in the transition speed-range has characteristics which would make it unacceptable to the pilot using existing handling criteria. Various forms of stability augmentation are possible, based in general on gyro-sensing equipment, and the following paragraphs aim at explaining the variations and outlining some of the problems which arise with automatic stabilization. Hovering is the worst stability condition encountered, so that the arguments will be developed with reference to this condition and extended to cover the effect of autostabilization at various forward speeds.

First of all, stability augmentation implies that, when a disturbance occurs, some characteristic of the aircraft is sensed, and the sensing element is used to apply a correcting force to oppose the disturbance. Simple sensing elements make it possible to sense the rate of rotation or the angle through which the aircraft rotates, and by using the related signals, or combinations of them, almost any desired characteristics can be achieved; assuming, of course, that a source of power is available to apply the correcting moments.

Consider first the characteristics in response to a control movement or external disturbing moment on the unstabilized hovering aircraft. Control is of the direct acceleration type, and it can be seen from Fig. 10 that in order to change attitude it is necessary to apply the stick, take it off, and then stop the motion by repeating the movement in the opposite direction. Such control can be difficult to execute with any precision, and it is not surprising that considerable concentration is needed on the part of the pilot to execute a manoeuvre even in calm air. The effect of external disturbances is shown in Fig. 11 and it can be seen that, if a steady moment is applied, angular acceleration of the aircraft is the result. The major trouble in handling an acceleration type of control is that, in the presence of unsteady external disturbances, the pilot under certain conditions can induce an oscillation owing to his response lag, and even in favourable circumstances cannot control to acceptable limits in aircraft attitude. Hence only in favourable conditions, when accuracy of control is not a fundamental requirement, could an

In the past . . . .

. . . . stabilizing systems were added to aircraft only to assist the pilot, but v.t.o.l. machines may prove to be uncontrollable without automatic stabilization.

One of the basic objects of a test vehicle is to investigate the principles of stabilization. The automatic stabilizing system must be broadly variable for the pilot, and even more for adjustment on the ground.

acceleration form of control prove acceptable, and the other possibilities i.e. damping, displacement, or integral control, are necessary when accurate manoeuvring or position holding is required.

The damping term

The easiest form of stability augmentation is provision of a moment opposite to the direction of motion and proportional to the rate of change of angular position. This can be sensed by a common rate gyroscope, a sturdy and well-proven sensing element, which has been in use on all types of damping systems for a considerable number of years. If such a feedback is provided, application of control results ultimately in a constant rate of change of attitude. Hence the stick movement necessary to change attitude is merely a displacement and a subsequent return to neutral, as can be seen from Fig. 10. Similarly, the effect of an external disturbance is to cause a rate of change of attitude (see Fig. 11) and any required rate of change of attitude for a given stick movement can be built into the system.

At speeds at which the aerodynamic forces are significant, the introduction of a damping term in either roll or yaw, depending on the aircraft configuration, will satisfactorily damp out the Dutch roll oscillation. Fig. 3 shows the resultant damping of this mode at various forward speeds for an amount of stabilization in roll likely to be adequate for hovering stability. Thus it can be seen that the Dutch roll oscillation, which is probably the most difficult oscillation to deal with in the transition speed-range, can be very much improved by the feedback provided for hover. Hence it appears that it may not be necessary to adapt the degree of stabilization to forward speed. In hovering, the amount of damping that would probably be necessary in the pitching plane would be similar to the amount necessary in the rolling plane; this will obviously improve the short-period damping but will have little effect on the phugoid. It should, of course, be noted that the introduction of an automatic damping term is equivalent to augmentation of the l_p or m_q derivatives, and the only limit to this is when the system becomes so well damped that it is too sluggish in manoeuvre.

The displacement term

The displacement of the aircraft about any axis can easily be obtained by using either a displacement gyroscope or, with a little more difficulty, by integrating the output of a rate gyroscope. Such a term cannot, of course, be used on its own to provide stability, and must be used in conjunction with some damping signal, i.e. there must be some phase advance. If the combination of damping and displacement feedback is correctly chosen, a stick movement will produce a steady new attitude, and a steady external moment will also cause a change in attitude as shown in Figs. 10 and 11. Such a form of control should undoubtedly be easier for the pilot, for not only will there be a direct relationship between stick position and aircraft attitude but also a direct relationship between aircraft-accelerating forces and stick position.

The effect of the introduction of position stabilizing terms on the roll axis is also shown in Fig. 3, and it

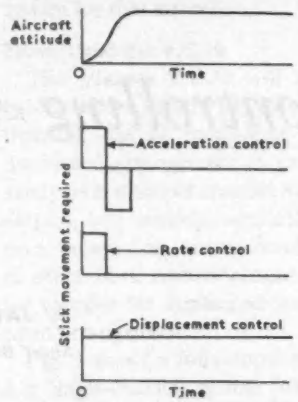


Fig. 10 Stick movements required with various forms of control for a given manœuvre

can be seen that here again, with a representative amount of displacement feedback present, the system stability is no longer a problem at any forward speed. A similar remark applies to the longitudinal short-period oscillation, and we are left with the thought that system response rather than damping is the basic design parameter.

The integral term

Displacement control is apparently satisfactory, and presents a one-to-one relationship between stick position and attitude except in the presence of externally applied moments. Throughout the transition on a v.t.o. aircraft, very considerable moments will result from engine-flow interaction with the airframe. This is mainly a function of airspeed and engine speed. These and other moments therefore vary quite significantly through a transition, and quite extensive stick movement would be required to trim them. If it is considered necessary to do this automatically, it becomes impera-

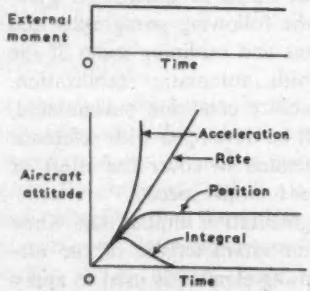


Fig. 11 Response to an external moment. The effect of different basic control laws is shown

tive to introduce an integral-of-attitude term, and this can be looked upon as performing the function of an automatic trimmer. There is certainly a case for such an extra control term on the pitch axis, and possibly also on the roll axis, and its characteristics are shown in Figs. 10 and 11. It can be arranged to respond to stick movement in identically the same way as for displacement control; assuming, of course, that the damp-

ing term is altered to achieve the same stability. In response to a steady external moment, however, the attitude will return to its datum after a transient. Thus we have a means of holding a constant attitude in the presence of changing external applied moment. The integral term, it may be observed, is a destabilizing signal in any control system, so that its inclusion should not be considered unless it is well established that simple damping and displacement feedbacks are not sufficient.

The effect of integral stabilization on Dutch roll stability at various forward speeds has been examined and the results are shown in Fig. 3. The parameters are chosen to allow a reasonable range of attitude control and to keep the disturbing effect of external gusts to the minimum compatible with system performance. The results show that reasonable stability characteristics can be achieved.

In general, then, it can be seen from the foregoing analysis that stability can be provided throughout the transition speed range with a stabilizer designed to give acceptable characteristics in hovering. Thus it is unlikely that any adaptive form of control will be necessary; or, more specifically, that it will be necessary to introduce changes in the feedback loop with forward speed. But the problem is not just one of achieving stability, for this must be associated with acceptable handling characteristics. Hence the introduction of the pilot, with his own peculiar servo-response characteristics, into the control loop. It is the performance of the human operator in carrying out a specific task which will finally decide how much and what form of stabilization will be required. However, the practical problem of actually providing the various stabilizing terms must always be weighed against the gain in having them. As an example of this: it is obviously possible to obtain a displacement signal from a free gyroscope, which tends to be heavy, fragile and subject to toppling trouble, or alternatively to get the signal from the integration of a rate-gyroscope output which tends to drift with time. Possibly the less precise signal is adequate for most applications. This example underlines the careful compromise which should be made between pilot requirements, system performance and equipment limitations.

Design requirements

On the introduction of any stability augmentation devices, two major issues must be faced:

1 What happens if autostabilization is lost?

2 What happens if a fault produces full stabilizing signal?

In the past the general principle has been that stabilizing systems were added to aircraft to assist the pilot, but there was seldom a suggestion that the pilot could not control the aircraft without them. A particular example of such a system is the yaw damper, which was installed in certain aircraft to improve heading control for aiming. If the stabilization failed, the success of the mission might well be impaired, but there was no suggestion that a return to base would not be possible. A v.t.o. aircraft will, in general, be stabilized about two, or possibly three, axes, and there is a very distinct possibility that without autostabilization a service pilot may not be able to control the aircraft. Whether such a pilot could cope with the aircraft under conditions in which stabilization was lost on one axis but still present on the other remains to be seen, and simulator evidence tends to indicate that it will be possible in favourable circumstances. If autostabilization is lost it appears that a multiplicity of channels on both axes will be necessary, if the pilot needs all-round stabilization, but that single-channel stabilization on both axes may be acceptable if the aircraft is still controllable with one axis out.

With regard to the second issue, what happens if a failure produces the full stabilizing signal, it is reasonable to expect that the application of full power will mean danger. We are forced to consider the possibility of restricting the authority of the autostabilizer so that,

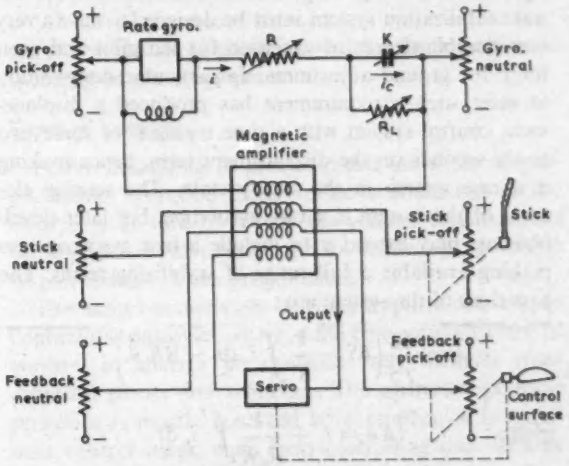


Fig. 12 Diagram of Short S.C.1 autostabilizer

if such a fault occurs, the change in aircraft attitude does not exceed some acceptable value. Calculations indicate that between 10% and 20% of full control moment could be used for stabilization without a dangerous condition arising should failure occur. Hence we see that single-channel autostabilizers in pitch and roll, where the stabilizing authority is restricted to 10% or 20% of full control moment, are a possibility. The other issue involved in such a system is, of course, whether with such restricted stabilizer authority the aircraft will be acceptable in normal gusty conditions. Here it should be remembered that the effect of gusts on normal aircraft is to change incidence and hence produce a disturbing force; but at zero forward-speed the effect is merely one of drag, and the gust which will give a normal acceleration of say 1g at 120 knots is unlikely to produce a normal acceleration of more than 0·05g at speeds below 20 knots. Hence only a small proportion of the control power should be essential for stabilizing, and the main requirement for power

is to control rather than to stabilize. Thus it may be that under visual conditions there is a case for a limited-authority, single-channel autostabilizer, and this would result in a light unsophisticated system which should prove very simple to manufacture and install.

For other than visual operation, especially when it may be necessary to do an instrument transition, there is little doubt that a full-authority stabilizer will be necessary. On the assumption that the aircraft is uncontrollable if autostabilization is lost, there does not appear to be any alternative to a multiplex system, which either automatically switches out a faulty channel or gives some indication to the pilot to enable *him* to switch it out. This can lead to considerable complications of equipment, but must be faced if a satisfactory flight system to cover transition on a v.t.o. aircraft is to be developed.

V.T.O. test vehicle

One of the basic objects of a v.t.o. test vehicle is investigation into the principles of stabilization. Hence the autostabilization system must be designed to have a very considerable degree of variation for the pilot and even more for ground adjustment. In particular, design study to meet such a requirement has produced a displacement control system with a time constant of some two to six seconds on the displacement term, hence making it a rate system in the steady state. The sensing element of the system is a rate gyroscope, but later developments may extend it to include a free gyroscope, so making available a full range of stabilizing terms. The equations of the system are:

$$\xi = \frac{\xi_m}{7{\cdot}5}\left\{6S - \frac{1}{K}\int i_c\,dt - RK\dot{\theta}\right\}$$

where

$$K\dot{\theta} = i_c + \frac{1}{R_L K}\int_0^t i_c\,dt$$

and

ξ is signal calling up control moment

ξ_m is signal which calls up full control moment

S is control-column displacement in degrees

θ is aircraft attitude in degrees

i_c is current through condenser K (see Fig. 12)

R, R_L and K are resistances and condenser values which are variable in the following fashion (see Fig. 12):

$R(\Omega)$	850	1050	1250	1450	1850	2350
$K(\mu F)$	300	600	900	1500	2100	
$R_L(\Omega)$	450	1200	2200	3900	12000	∞

An illustrative block diagram is shown on Fig. 12.

An electric spring rate gyroscope is used as the primary sensing element. As the gyroscope deflects, its potentiometer-wiper moves away from the neutral position and causes a current to flow in the torque coil. This in turn exerts a restraining force on the gimbals, and a balance point is reached. A condenser is included in the torque coil circuit so that the voltage developed across it is proportional to the time integral of the current; thus the voltage developed across the whole circuit contains components proportional to both aircraft attitude and aircraft displacement rate. Owing to equipment limitations, it is necessary to include a leak path across condenser K: the system is not then, strictly speaking, a pure displacement control. The signals are fed into a magnetic amplifier, and from thence to a torque motor operating a valve that supplies oil to the pistons of a hydraulic actuator. The displacement of the valve is continuously monitored by a miniature a.c. linear pick-off, and the system is completed with a solenoid-operated, hydraulic, supply-isolation and cylinder-interconnexion valve. The system is completely triplicated up to the output of the hydraulic actuators. The latter drive a common shaft, and misalignment of the servo-valve position is used to detect a fault.

Position stabilization

So far we have only discussed stabilization about the aircraft axis. There is, of course, another major problem, that of positional stabilization in space. Referring again to the hovering aircraft; the control of height is through the lift throttle, and the control of position in plan is by pitching or rolling the aircraft until a component of lift is obtained which accelerates the aircraft in the required direction. So we have acceleration fourth-order controls in X-Y-Z directions referred to the unstabilized aircraft. Whilst this may be adequate for slow manoeuvring, it must suffer from the usual limitations of high-order control.

Stabilization of the X-Y control has not been considered, but some thought has been given to height stabilization. The necessity for this will be largely a function of the thrust response of the engine, and may well occur in the case where a single large engine, rather than a multiplicity of small engines, is used to provide vertical thrust. Preliminary investigations of this matter have shown that a simple accelerometer type of control, in which an acceleration error in the vertical direction will impose a reduction of engine thrust, is an asset. This will of course merely reduce the acceleration caused by any given disturbing force, and will not reduce the order of control involved. It is possible also to integrate this signal so that a disturbing force gives a rate of change of height, and thus the throttle becomes a rate-demand control.

NEXT MONTH

Control of s.t.o.l. and v.t.o.l. aircraft involves problems that lie right outside the present range of flying experience. In next month's instalment Foody will critically examine these problems and also review American machines.

Programming a digital computer for process control

Special problems confront the programmer of a digital computer designed for process control. Radically new approaches may emerge from the meeting of control engineering and computer programming disciplines.

T. H. GOSSLING, B.A.
Ferranti Ltd

THE ENTRY OF DIGITAL COMPUTERS INTO THE PROCESS control field makes possible new and more sophisticated forms of control, both in those processes where automatic control is already established and in those where the limitations of conventional control equipment prohibit the setting up of a practical system. This sophistication trails many problems in its wake, amongst which are those of analysis of the resultant process behaviour, and the translation of the required modes of control into an actual program, which is discussed here.

Obviously, there are large areas of similarity in programming between all kinds of digital computers, and many of the techniques developed for general-purpose machines can be carried over almost unmodified into the control field. Consequently we shall not discuss these in any detail, but rather take them as read, and concentrate on the specialized techniques that must be learnt and developed. The meeting of the two separate disciplines of control engineering and computer programming has presented a challenge to both which may well produce some radically new methods of approach.

The operations that an on-line digital computer may be expected to perform fall broadly into two categories: control and data handling (or logging). Either or both of these may be used in any given application—particularly when the computer is first installed. Even when no control work is envisaged, an on-line computer can be an aid in obtaining the most usable kind of information concerning the operation of the process, thus saving a great deal of the external computation that is often performed on conventional operating records. In many cases, it may be preferable initially to install the computer for logging only, extending its functions to include control at a later stage—one of the attractive features of a digital computer is the flexible way in which modifications of this sort can be made, merely by change of program, without disproportionate spending on extra equipment.

Types of control

Before discussing in greater detail the types of programming operation likely to be encountered in the field, it is as well to review the general classifications of application involved, and to define the probable responsibilities of the programmer.

The most immediately obvious applications are to continuous processes where some conventional form of control is already in existence; this includes most chemical plants and refineries. The operation of these processes is mostly governed by a number of independent control loops, each loop controlling one variable without reference to the others. Since these variables are connected by the process itself, it is theoretically possible to make improvements in the overall efficiency by a complementary interconnexion of control elements, difficult to achieve with existing equipment. The computer may here only provide the link between the control loops, the conventional loop controllers being retained, or it may also replace the controllers themselves; the latter method makes possible some very sophisticated systems. In either case, most of the process equations and desirable control features will be provided by the engineers responsible for plant design, and the programmer's job will be to translate these into computer coding, a matter of standard numerical analysis technique, although with some new features. Most of the equations involve differential operators with respect to time, associated with which are certain difficulties mentioned below.

The second type of control application is the batch process. The problems here are basically the same as for a continuous process, and in many cases conventional controllers are already in use. However, instead

of holding variables at constant values, a timed cycle of operations is required, and this is usually achieved by an elementary timer, such as a motor-driven cam. To show significant advantages, the digital computer program must improve on this necessarily fixed cycle, and adjust the future timing appropriately as the batch progresses. For economic reasons, the object is usually to minimize some overall criterion (such as the time for the batch); this criterion can be expressed as an integral of other variables, so that the calculus of variations can be employed. Again, most of the necessary equations can be provided by the designers, and their implementation is a matter of numerical analysis.

Leaving the realms where conventional controllers have already provided some experience, we come to more esoteric forms of 'control' to which they are by nature unsuited. Here the digital computer should, in theory, be able to make a new contribution, but some new programming techniques will also be needed.

Most of these fields suggest that the computer should be used as a logical device as well as an arithmetical calculator. Specific examples are found in various forms of traffic control. In these cases, only the broad outlines of what is required can be expected from the customer, and the programmer will probably have a considerable share in devising a theoretical form of solution, besides translating it into actual orders. As a kind of hybrid between logical control and the batch process, we can give here the example of the starting-up of boilers for power stations, where digital computers are already establishing themselves.

A further possibility is the control of such large organizations as the National Grid. This would be an exercise in the established technique of linear programming. It also raises the possibility of having one computer in overall control of several others; in this example the latter would be those controlling the power stations (regarded as continuous processes). This will obviously produce some problems in co-ordination.

Logging

As has been remarked above, the information that an on-line computer can give concerning the operation of the process makes it worth installing even on some of those plants where no significant improvement can be expected in control performance. This information can be used to compile an operating guide for future use, and can also be of considerable assistance in designing new plant.

The conventional chart record, while providing a good overall picture at a glance, is inconvenient where further computation has to be done at a later date to estimate efficiencies and similar criteria; taking readings from a graph, which may be on a non-linear scale, is inconvenient, and a source of error. At its most elementary level, the function of a computer is therefore to present a printed record in a readable form, scaled into normal physical units, and with the non-linearities corrected. Slightly more sophisticated is the recombination of these readings into operating criteria, from elementary averages up to compound figures of merit, thus eliminating much of the later hand-computation. At its most advanced level, the computer can analyse the behaviour of the process continuously, for checking against existing mathematical models. This involves finding transfer functions and frequency responses from correlation measurements in linear cases, and more general describing functions elsewhere.

The elementary levels of logging require conventional functional operations (for non-linear measurements), discussed in greater detail below, and the normal procedures for deriving decimal digits and controlling the layout of the printed record. Most of these operations can follow the lines used on general-purpose computers. Compound criteria will usually require the handling of integrals, of which time-averages are a simple example. Where these integrals are large, the accumulation of rounding-off and other errors needs watching, and often demands higher accuracy than normal in the intermediate stages.

The printed record referred to above is that provided by the standard printing device normally supplied with the computer, an electric typewriter or teleprinter, or punched-card equipment. This will normally handle the bulk of the information, including the hourly or daily averages, and alarms from monitoring points. It often happens that the more random information—alarm in particular—comes in at a rate which is temporarily too great for the maximum speed of the printer. In control work, the computer must not be held up by this, and some system for forming a 'queue' has to be organized, using the computer store as a buffer to hold the surplus; the use of the computer to spread the load in this way saves expenditure on extra information-channels, only used on peaks of demand. The queue may consist of numbers in binary form, for processing into decimals as the printer becomes available, or the decimals themselves may be held complete with auxiliary symbols, such as sign and point, and layout control. The latter form, although slightly more expensive in storage space even where characters are packed into computer words, is often more convenient, particularly if the printed sheet is to be enriched with alphabetic material.

So far as possible, the printed record should be kept to a minimum, for ease of reading, by including only those items which are known always to be required. Later examination of this record may reveal periods when the correct functioning of the process is in doubt, and detailed information may be desirable on these for 'post-mortem' investigation. Some form of cheap semi-permanent record in considerable detail may therefore be desirable, in a form which can be discarded unless such an investigation is required. Here some of the more compact forms of storage associated with digital computers come into their own, notably magnetic and paper tapes. Since most of the information will never be used, it is most economical to record

it in as condensed a form as possible — usually as binary numbers straight from the computer. When a section of this is required for reading, it can be processed into printed form, usually on another (general-purpose) computer. Where it is preferable to store numbers in decimal form, the speed of the equipment, particularly magnetic tape, is such that this cannot conveniently be done by program, and the programmer's task can be eased considerably by the use of external equipment now available to convert binary numbers into binary-coded decimal digits.

Timing

Perhaps the most significant difference between general-purpose digital computers and those designed for on-line work is the introduction of the dimension of *time*. On nearly all digital machines, the time taken for certain of the fundamental operations, e.g., multiplication, is not constant, depending on the numbers involved; consequently it is not possible to predict the precise period of time that will be taken by any particular section of program. In general-purpose work

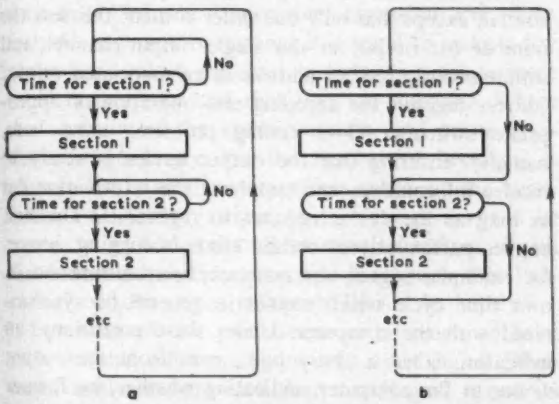


Fig. 1 Typical flow diagrams for timing by clock input. **a** All sections have same repetition period τ (although staggered in time). The outer loop is also traversed with period τ. **b** Sections have different periods, chosen so that no two sections coincide in time. The outer loop is traversed as fast as possible whenever none of the sections is operative

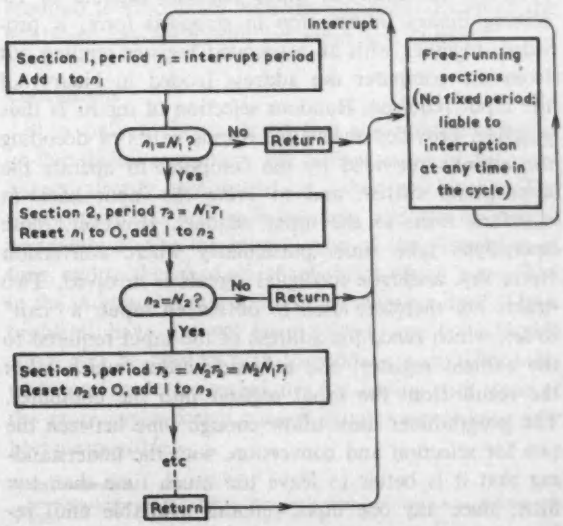
this is not of great importance, provided an approximate estimate can be made, but in control work, particularly where sampled-data theory is involved, precision in the timing of certain operations is a basic assumption, and if this is violated some unwelcome effects can result. Some means of keeping a check on the passage of time must therefore be provided.

The obvious method is to provide a clock as an input to the computer. This clock will not, of course, be limited to hours, minutes and seconds only, but will be based on a far finer unit whose size will be related to the speed of the computer and the acceptable tolerance for timed operations. An approximate check can be kept in terms of the known maximum timings for the orders in the program, and when a suitable total has been reached the clock can be inspected at suitably frequent intervals, until the exact time (to within the prescribed tolerance) has been reached.

This method, while adequate in many cases, has certain drawbacks. Frequent inspection of the clock involves a considerable waste of program time; this is unimportant where the entire program is built up of sections each of which is initiated at regular intervals, as the time between sections is in any case wasted, and may as well be occupied by a loop-stop conditional on the state of the clock—typical flow diagrams are shown in Fig. 1. It often happens, however, that the exact timing of some parts of the program is unimportant, the requirement being that as much as possible be done in the available time; an example is the readjustment of control constants in self-adaptive systems. The clock input is unsatisfactory here, and another method has to be found.

The alternative is what is known as a 'timer-interrupt' facility. The clock is brought inside the computer, and given power of control over the sequence of orders in the program. The timer is, in fact, a simple register holding an integer which is counted down by unity at a fixed rate, independently of the operations performed by the computer; when it reaches zero, the program is interrupted and a special 'interrupt sequence' is entered, a record being kept of the point at which the main program is broken. The integer in the timer can be reset by program to any value, thus making possible any length of interrupt period, regular or irregular. Often there are various timed operations to be performed with different (but fixed) periods; the interrupt period can be set to some common factor of these, and counters employed in the interrupt sequence to produce the appropriate timings for each section. A simple case is shown in Fig. 2, where the periods are

Fig. 2 Flow diagram for timing by 'interrupt', where the periods of the timed sections are successive multiples of one another. The slower-running sections are not initiated exactly at 'interrupt', having to wait for the faster sections; if the latter take very variable times to complete, this may introduce intolerable timing errors. The alternative is an arrangement similar to that shown in Fig. 1b. This can also be used in more complex timing schemes. All free time is taken up by free-running sections



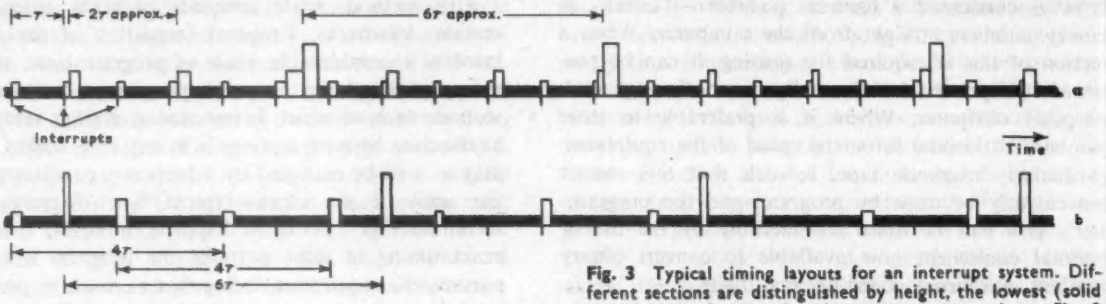


Fig. 3 Typical timing layouts for an interrupt system. Different sections are distinguished by height, the lowest (solid black) being free-running. Layout a corresponds to Fig. 2 with section timings of τ, 2τ, and 6τ. It can be seen that the timings of the last two fluctuate slightly about their means. In b, the alternative scheme, the flow chart for the timed sections is similar to Fig. 1b, and the timing of each section is exact (at periods of 4τ, 4τ, and 6τ). Some interrupts are apparently wasted, but are actually occupied with a brief organization sequence, advancing counters by 1 and returning immediately to the free-running section

successive multiples of one another — more complex schemes are easily arranged. If any parts of the program are free-running (as in the self-adaptive system above) the interrupt sequence is terminated by a special 'return' order, which restores control to the main program at the point where it was broken.

Whichever timing system is used, if multiple periods for various operations are required, some initial planning of the program on a time axis is advisable, showing relative positions of the sections and the maximum time taken by each. Examples for timer-interrupt systems are shown in Fig. 3.

Input and output

General-purpose computers normally have only a small number of inputs and outputs, relatively slow in operation; input and output operations are not the major part of a program and the devices used are therefore permitted to hold up the computer. In control computers this is no longer a reasonable design philosophy, as has already been noted in connexion with printing.

In theory, a computer used in any kind of control application requires a large number of independent inputs, but in practice, since the computer can only read one at a time, a single input-channel is sufficient, with some means of switching this to different sources on program demand. An input register, capable of receiving binary information in standard form, is provided, together with an associated register sending out from the computer the address (coded in binary) of the input required. Random selection of inputs is thus possible, provided that some means exists of decoding the address provided by the computer to operate the appropriate switch, and to bring the input back in standard form to the input channel. However, these operations take time, particularly where conversion from, say, analogue to digital signals is involved. Two orders are therefore used to obtain an input: a 'call' order, which sends the address of the input required to the address register; and a 'read' order, which takes the result from the input register into the computer. The programmer must allow enough time between the two for selection and conversion, with the understanding that it is better to leave too much time than too little, since any one input remains available until replaced by another. In this the programmer must have the co-operation of the engineer designing the switching system.

The situation with respect to outputs is basically similar, except that only one order is used; this sets the number for output in the single output-channel and simultaneously sets an address in an associated output address register, for decoding and operation of appropriate switching. Two timing problems arise here, namely: ensuring that the output device is ready to receive information; and supplying the information for as long as the device requires to register it. The first applies particularly to certain kinds of logging device; for example, a gang summary card-punch runs on its own time cycle which cannot in general be synchronized with the computer. Under these conditions, an indicator, called a 'busy line', runs from the output device to the computer, indicating whether the former is ready to receive information. A busy line is a kind of single-bit input which by-passes the input addressing system and is continuously available, the computer being designed to take a limited number of these. The busy line appropriate to each device must be inspected by program before sending information—this applies also to electric typewriters, where used, and to some input devices. The holding of information for the operating time of an output device is partly a matter of program, since information remains in the output register until a new output is sent. Digital and analogue holds are usually necessary in any case, which relieves the programmer of responsibility here, but where digital holds are electromechanical holding relays only, some care may be needed.

The timing of certain input or output devices is sometimes so critical that the necessary frequency of busy tests is a strain on the program, an example being magnetic tape. Direct access to the store of the computer can be provided in these cases, so that the programmer merely takes information directly from appropriate core store locations (or sends it to them), and leaves the timing of the actual transfer to or from

the device to be arranged automatically. Direct-access systems are sometimes used in conjunction with rotation scanning for ordinary inputs, but it is not advisable to rely on this alone, since the rate of scanning is fixed by the fastest-changing input, and may be unnecessarily high for inputs seldom required, thus saturating the input channels with redundant information.

Digital inputs and outputs, particularly single bits from limit switches, etc., are usually packed into words to suit the input and output registers, in order to save addresses, and the programmer must expect to make full use of logical orders, particularly collation (logical '&').

Functional operations within computer

The computational operations within the computer itself, both in control and logging, can follow the lines already established for general-purpose machines. However, some time and storage can be saved by not adhering to existing subroutine specifications, particularly where function generation to low accuracy is concerned. Most functions are generated by an iterative process, such as a Chebyshev polynomial expansion, and where forty-bit accuracy is required it is usual to make a few preliminary transformations, in order to produce more rapid convergence and thus save on iterations. Where the accuracy of the instrumentation, and hence functions, is poor, say 1%, the number of iterations is already low, and the extra orders taken by the transformation are not justified by the savings that can be made. In general, subroutines must be written to suit the individual requirements, which suggests that 'libraries' of subroutines will probably not be kept.

Functions of time can sometimes be generated from their defining differential equations, as in digital differential analysers, provided that rounding-off errors do not accumulate; this is most useful for trigonometrical functions. In general, some care is needed in the handling of differential operators of time functions, as unpleasantly fluctuating results can arise from the use of the simple difference method on slowly varying quantities.

Program checking

In all that has been said above, it has been implicitly assumed that the programmer is capable of producing a program that is guaranteed to produce the right results under all possible circumstances. In practice, as any programmer knows, it just is not possible to write a program of any length and be sure that it will work first time; several development runs are normally required in order to eradicate all errors. Obviously even a minor error (in the sign of a number for example) could have disastrous consequences in the control of an inherently unstable process, and trial runs in many (though not quite all) applications are out of the question, except in those restricted purely to logging.

The approach adopted to overcome this difficulty depends on the process. The most obvious is to use some kind of simulator for the process. A completely accurate image is not always necessary, even when this is known, and a linearized model, suitable for analogue simulation, is often sufficient to bring the program to a state where it can safely be applied to the actual process. Some care is needed, even so, to ensure that 'minor' errors in the simulator (again, in sign, say) are not compensating for errors in the program.

As a preliminary measure, it may be helpful to test sections of program individually. This need only use the simplest equipment, feeding in numbers by hand and observing the results on the monitoring facilities of the computer. Even so, errors can creep in during assembly, and a test of the complete program is still necessary.

Where analogue simulation is not possible, digital simulation provides an alternative, if we assume that the laws governing the process are at least approximately known. Two paths are open: first, another on-line computer may be used as a simulator, inputs being connected to the outputs of the control computer and vice versa; second, the entire problem, including control, may be programmed for a general-purpose computer, not necessarily working in real time. Both these methods are open, even more than with analogue simulation, to the objection that errors may be present on the simulation side. However, it is possible that these might be overcome by the provision of a specialized interpretative scheme, automatically writing a complete simulation program from coded basic equations. In addition, the transfer from the control computer to the general-purpose computer in the second case is a source of error, which might also be avoided by using computers of similar types, with an automatic interpretive scheme between one and the other.

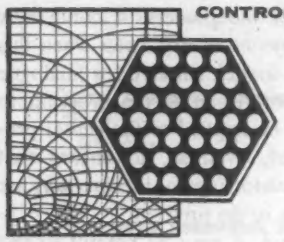
It is therefore fairly evident that checking of control programs is going to be a major problem, and it is doubtful whether the programmer can be expected to do all the work himself. He will probably need to have considerable backing in the form of analogue and general-purpose digital computer facilities, and will be required to co-operate with the engineers designing the hardware and equipment for input and output.

Conclusions

It is only to be expected that the programming of on-line digital computers will borrow many of the techniques already established on other machines. The special problems arising in this new field can be seen to be mainly due to the introduction of the dimension of time, and to the standard of reliability which is required in the program as much as in the computer itself. These problems have not yet been solved, and considerable effort will be needed both to produce acceptable solutions, and to derive techniques for dealing with some of the more sophisticated control situations that have now become possible.

Acknowledgement

Acknowledgements are due to Ferranti Ltd for permission to publish this article.



CONTROLLING NUCLEAR POWER—2

PART B

These are the transfer functions in the block diagram for a nuclear power reactor system

Automatic control of power reactor systems

by **J. H. BOWEN**

U.K. Atomic Energy Authority

Last month we introduced the problems of temperature control and power control in nuclear reactors, and stated that an approximate analysis of stability is possible by linearizing the equations. Having given a block diagram of the system (as repeated above), we opened a discussion of the individual transfer functions. This is continued below.

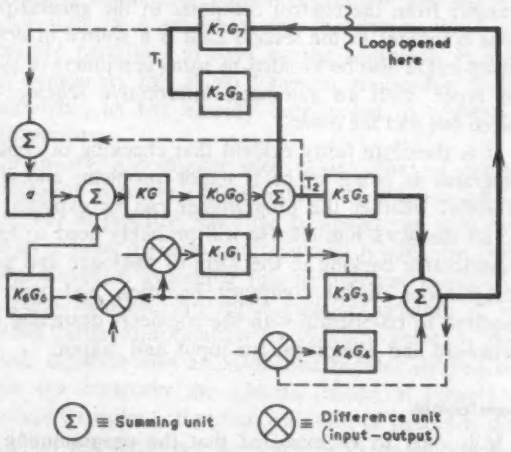


Fig. 2 Control diagram. a = temperature coefficient. KG = $P/\delta k$. $K_0G_0 = T_2/P$. $K_1G_1 = (T_2/T_{2E})$ due to blowers. $K_2G_2 = T_2/T_1$. $K_3G_3 = (T_1/T_{2E})$ due to blowers. $K_4G_4 = (T_1/T_{1E})$ due to steam pressure. $K_5G_5 = T_1/T_2$. $K_6G_6 = k/T_{2E}$. K_7G_7 = gas transport lag

K_0G_0 denotes the Laplace transform of the gas outlet temperature T_2 as a function of the reactor power P. The heat transfer relationships are discussed in (*2*).

We regret the misprinting of a minus for a plus sign in the denominator of the expression defining k_c in our August issue. The expression appeared at the top of the r.h. column on p. 106.—EDITOR.

Although the bulk mixed-gas temperature at outlet is well defined, in general the reactor temperatures even for a given component vary considerably from one point to another; and, if under transient conditions these alter relatively to one another, the problem must involve partial differential equations and become intractable to servo-mechanical analysis. However, the conditions have been established (*2, 3*) under which the components may be regarded as lumped parameters; among the conditions is that the transit time of the fluid through the reactor channels should be short compared with the periods of the frequencies of interest. These conditions will be assumed to apply, and the process of heat flow may be represented as shown in Fig. 4. R_1 is a resistance to heat flow from the reactor fuel element to the coolant fluid; C_1 represents the thermal capacity of the fuel elements. R_2 is a measure of the heat conveyed out of the reactor core by convection,

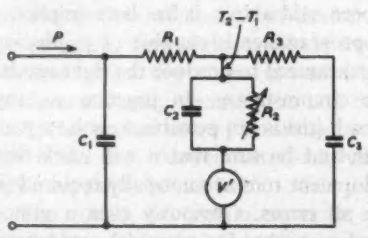


Fig. 4 Equivalent circuit for flow of heat in reactor

and C_2 represents the thermal capacity of the coolant fluid. Similarly, R_2 and C_3 represent the 'side capacities', e.g. of the moderator. The heat capacity of the coolant fluid C_2 is usually negligible compared with C_1 and C_3. Making this approximation we find that the transfer function becomes:

$$T_2/P = \frac{1+p\tau_3}{\frac{1}{R_2}+p\left\{\left(\frac{1}{R_2}+\frac{1}{R_3}\right)\tau_3+\left(\frac{1}{R_1}+\frac{1}{R_2}\right)\tau_1\right\}+p^2\tau_1\tau_3\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)} \quad (11)$$

$$\tau_1 = R_1C_1 \qquad \tau_3 = R_3C_3$$

Considering a Stage-1 reactor, under full-power conditions, typical values are:

$$\tau_1 = 10 \text{ sec} \qquad \tau_3 = 10^3 \text{ sec}$$

$1/R_1 = 1$ MW/°C $\quad 1/R_2 = 2$ MW/°C $\quad 1/R_3 = 1$ MW/°C.

An alternative method of construction reduces the side capacities, giving $\tau_3 = 10^2$ sec. The frequency diagrams for the two cases are shown in Fig. 5.

K_1G_1 involves (a) the change induced in the fluid mass flow by a temperature error signal; (b) the response of the reactor temperatures, in particular the coolant outlet temperatures, to the change in mass flow.

(a) If, as is usual, flow is controlled by regulating the speed of the pump or circulator, the mass flow may be taken as proportional to the circulator speed, since the compression ratio used for reactor cooling seldom exceeds 1·1. The flow changes with a lag depending on the inertia and the accelerating force. Other time constants, e.g. magnet-field time constants, or time constants due to the inertia of the fluid, although neglected here, require to be established in design. In a 2200-h.p. machine, with a moment of inertia of 33,000 lb ft², 20% regulation, 500 V at full load, and full speed of 1000 rev/min, the time constant in seconds is given by I/K, where I = inertia (lb ft²) and K is the accelerating torque (foot poundals) per unit difference from synchronous speed (radians per second). From the data given,

$$\text{Motor torque} = \frac{2200 \times 33000 \times 32}{200 \times 100}$$

$$\text{Motor current} = \frac{2200 \times 746}{500 \times 0{\cdot}9} \text{ A (Assuming 90\% efficiency)}$$

$\therefore$ Motor torque per unit current = 101 ft pdl/A

$$\text{Motor volts per unit angular velocity} = \frac{500 \times 60}{2 \times 1000} = 4{\cdot}77 \text{ V/rad sec}$$

$$\text{Motor resistance} = \frac{500^2 \times {\cdot}9 \times 0{\cdot}2}{2200 \times 746} = 2{\cdot}9\ 10^{-2}\ \Omega$$

$\therefore$ Torque per unit angular velocity $= \frac{101 \times 4{\cdot}77}{2{\cdot}9\ 10^{-3}} = 1{\cdot}66\ 10^4$ ft pdl/rad sec

$\therefore$ Time constant $\tau_4 = I/K = 2$ sec

The 'gain' of this section, i.e. change of speed per unit temperature error, is one of the disposable parameters; a value of 50 rev/min per unit temperature error (1°C) will be assumed for this example.

(b) Referring to Fig. 4, it is required to determine the transfer function relating to T_2 as R_2 is varied. This problem involves time-varying coefficients in the differential equation, but a solution may be obtained by considering small perturbations of R_2, i.e. varying

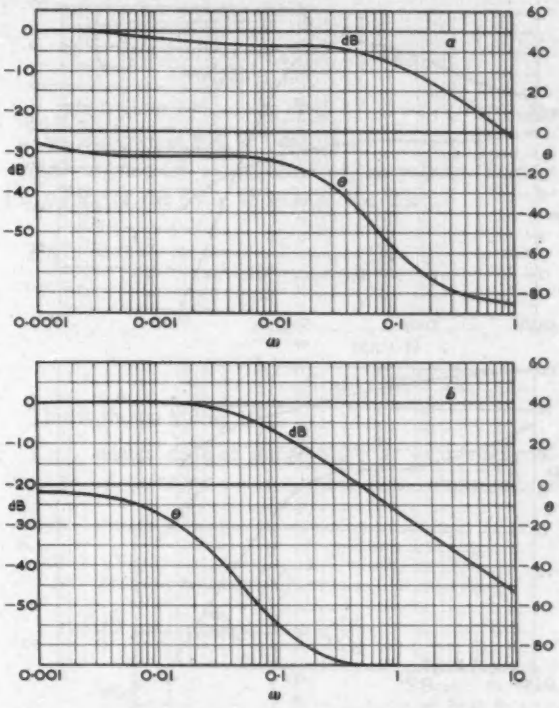


Fig. 5 Frequency diagrams for $K_0G_0 = T_2(p)/P(p)$ for two values of graphite thermal time-constant: (a) $\tau_3 = 10^3$ sec, $K_0G_0 = (1 + p10^3)/2(1 + p1515 + p^2 2 \times 10^4)$. (b) $\tau_3 = 10^2$ sec, $K_0G_0 = (1 + p10^2)/2(1 + p115 + p^2 2 \times 10^3)$

by a small deviation R_2' about a mean level R_2. Denoting the perturbation of T_2 by T_2',

$$\frac{T_2'}{1/R_2'} = -\frac{T_2}{1/R_2}\left(\frac{1}{1+p\tau_3}\right) \quad (12)$$

Since $1/R_2$ and $1/R_2'$ are proportional to mass flow and change of mass flow respectively, they may also be replaced by their equivalent circulator speeds.

Combining (a) and (b)

$$K_1G_1 = \left[50\frac{\text{rev/min}}{°\text{C}}\left(\frac{1}{1+p\tau_4}\right)\right]\left[\frac{200°\text{C}}{1000 \text{ rev/min}}\left(\frac{1}{1+p\tau_3}\right)\right] \quad (13)$$

(assuming that, at full blower speed, T_2 has the value of 200°C).

$$\therefore\ K_1G_1 = 10\left[\frac{1}{1+p\tau_4}\right]\left[\frac{1}{1+p\tau_3}\right] \quad (14)$$

where τ_3 (as before) = 10^2 sec or 10^3 sec

τ_4 = 2 sec (from (a) above).

The frequency diagram for K_1G_1 is shown in Fig. 6.

K_2G_2 relates fluid temperature at reactor outlet T_2 to that at reactor inlet T_1. In the equivalent circuit of Fig. 4, voltages represent temperatures above reactor inlet temperature T_1; but the effect of a small change

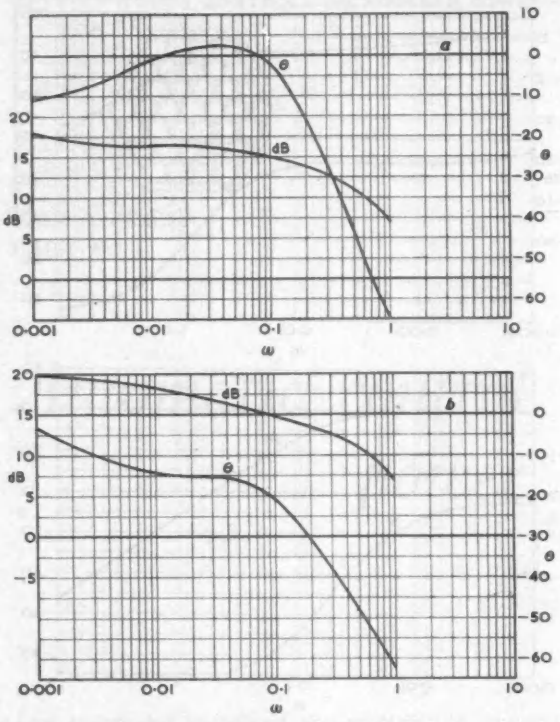


Fig. 6 Frequency diagrams for $K_1G_1 = T_2/T_{2(error)}$ for two values of graphite thermal time constants: (a) $\tau_3 = 11^3$ sec, $K_1G_1 = 10/(1+p^2)(1+p10^3)$. (b) $\tau_3 = 10^2$ sec, $K_1G_1 = 10/(1+p^2)(1+p10^2)$

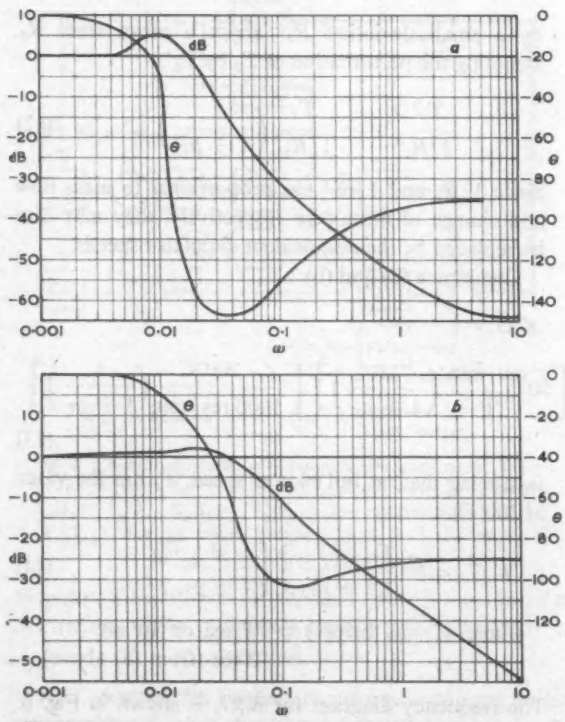


Fig. 7 Frequency diagrams for $K_2G_2 = T_2/T_1$ for two values of graphite thermal time constants: (a) $\tau_3 = 10^3$ sec, $K_2G_2 = (1+p1010+p^2104)/(1+p1010+p^23{\cdot}5\times10^4+p^35{\cdot}05\times10^6)$. (b) $\tau_3 = 10^2$ sec, $K_2G_2 = (1+p110+p^2103)/(1+p110+p^23{\cdot}5\times10^3+p^35{\cdot}5\times10^4)$

T_1' in the latter may be represented by the interpolation of an equivalent voltage V' as shown in Fig. 4.

$$K_2G_2 = \frac{V_2'}{V_1'} = \frac{1+p(\tau_1+\tau_3)+p^2\tau_1\tau_3}{1+p(\tau_1+\tau_3)+p^2\tau_1\tau_3\left[1+\frac{R_2}{R_1}+\frac{R_2}{R_3}\right]} + p^3\tau_1\tau_3\left(\frac{R_3}{R_2}\tau_3+\frac{R_2}{R_1}\tau_1\right) \quad (15)$$

The frequency diagram using the values already quoted is shown in Fig. 7.

Steam-raising unit

The heat-transfer fluid is usually in counter-flow to the working substance, which may exist in several phases, usually water, water-steam mixture, and superheated steam. The process may be represented in increasing detail:

(a) Considering only one process, e.g. supplying latent heat of evaporation to water at boiling temperatures, and representing this by lumped parameters.

(b) As (a), but allowing for the distributed nature of the process. The appropriate transfer functions are given by Takahashi (*4*).

(c) Allowing for several processes in tandem.

(d) Allowing for local feedback loops, e.g. feed-water regulators, and the effects of recirculation from steam drums.

In this example a purely illustrative model is employed which reasonably reproduces the characteristics of a typical s.r.u. as regards output and input temperatures, effect of steam pressure, and effect of flow, at frequencies below about a cycle a minute. The process may be represented by the equivalent electrical circuit, Fig. 8, in which T_2 represents the primary fluid temperature at entry to the s.r.u., and T_1 its temperature at exit. A temperature intermediate between these ($\bar{T}$) is the 'effective' temperature for heat transfer, T_3 being the secondary-side temperature, whilst fR_s represents the heat transfer resistance. aR_s, bR_s and gR_s represent sinks of heat in the primary circuit, current being the analogue of heat flow. T_1/gR_s represents the heat contained in the primary fluid (measured above some convenient datum) at exit from the s.r.u. If the primary coolant mass flow rate is reduced, the resistance should be increased if the same correspondence between temperature and heat flow, and voltage and current flow is to be maintained. Small changes of mass flow do not alter the ratios a, b and g. Thus the effect of changing mass flow may be represented by inverse changes of R_s. The heat transfer resistance fR_s also changes with primary mass flow rate. If the primary coolant is a gas, the bulk of the resistance is at the gas-tube interface, and it may be shown that this resistance varies inversely as (mass flow)$^{0\cdot8}$. If for small changes, fR_s is taken as approximately inversely proportional to

the flow, then f may be treated along with a, b and g as a constant for a particular design, and for small changes about a defined working point.

The capacity C_s, together with the flow resistances, represents the mixing lag of the primary fluid in the heat exchanger. This time constant is given by the circuit volume from heat source to heat sink, divided by the volume flow rate. A typical full-load value for a Stage-1 station is about 10 sec. R_e represents the impedance of the load (e.g. turbine) whilst C_e represents the thermal capacity of the secondary fluid plus the associated metal of the tubes. At full load the time-constant fR_sC_e might be approximately 30 sec. Typical values for these components are shown in Fig. 8.

The transfer functions depend on the method of operation of the s.r.u. Methods fall into two broad categories:

(a) Steam pressure (and temperature) allowed to vary with load.

(b) Steam pressure controlled either to remain at a constant value or to follow a predetermined program with load.

The latter is assumed in the present example. The effective load impedance would be varied by a steam throttle valve, automatically controlled to regulate T_s at the demanded level T_{sd}. Since there is no practical difficulty in making this regulator have good high-frequency response, its transfer function is not explicitly included, i.e. a gain of unity and a phase lag of zero is assumed over the frequency range of interest.

K_4G_4 is the open-loop transfer function between T_s and a change R_e' in R_e. It is approximately

$$\frac{T_s}{R_e'} = \frac{T_s(b+g)}{(a+b+g)[(a+f)R_s+R_e]-a^2R_s} \times \left[1-\frac{(a+b+g)R_e}{(a+b+g)[(a+f)R_s+R_e]-a^2R_s}\right]\left[\frac{1}{1+p\tau_e}\right] \tag{17}$$

$$= K_7/(1+p\tau_e) \qquad \text{where } \tau_e = R_eC_e$$

The gain of this regulator is:

Change of R_e per unit temperature error $=$

$$= R_e'/T_{2E}K_s \text{ (say).}$$

The open-loop transfer function is: $K_7K_s/(1+\tau_e)$

The closed-loop transfer function is:

$$\frac{T_s}{T_{sd}} = \left(\frac{1}{1+1/K_7K_s}\right)\left(\frac{1}{1+p\tau_e/(1+1/K_7K_s)}\right) \tag{18}$$

The open-loop response, T_1 to T_s is

$$\frac{T_1}{T_s} = \frac{ga}{(a+f)(b+g)+af} \cdot \frac{1}{1+\dfrac{g[b(a+f)+af]}{(a+f)(b+g)+af}p\tau_s} \tag{19}$$

$$= K_8/(1+pK_{10}\tau_s) \tag{20}$$

(say), where $\tau_s = R_sC_s$

$$\therefore \frac{T_1}{T_{sd}} = \left(\frac{K_8}{1+(1/K_7K_8)}\right) \times \left(\frac{1}{1+\dfrac{1}{1+K_7K_8}p\tau_e}\right)\left(\frac{1}{1+pK_{10}\tau_s}\right) \tag{21}$$

$$\therefore K_4G_4 = T_1/T_{1E} = T_1/T_{sd} \tag{22}$$

This is shown in Fig. 9.

K_5G_5 relates the temperature of the primary fluid at the outlet of the s.r.u. to that at the inlet.

$$K_5G_5 = \frac{T_1}{T_2} = \frac{fg}{af+(b+g)(a+f)} \times \frac{1}{1+p\dfrac{b(a+f)}{af+(b+g)(a+f)}\tau_s} \tag{23}$$

This is shown in Fig. 10.

K_3G_3 relates coolant temperature at s.r.u. outlet to changes of primary coolant mass flow, expressed as

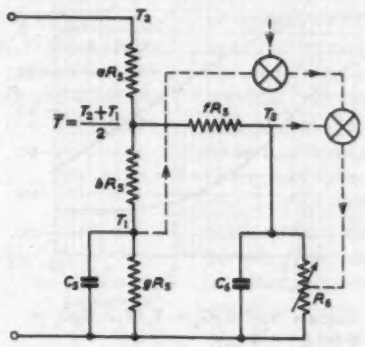


Fig. 8 Equivalent circuit for flow of heat in s.r.u.

changes of temperature-demand to the input of the circulator speed control. Changes of mass flow are represented by changes in R_s; but T_1 is independent of R_s (T_2 and T_s remaining constant). Thus K_3G_3, for the constant-steam-pressure mode of control, is zero.

K_6G_6 relates reactivity-change due to control-rod movement to temperature error T_{2E}. Assuming that the control-rod speed is made proportional to the temperature error, lags in the controller may be neglected at frequencies lower than 1 c/s, giving:

$$\delta k/T_{2E} = K_6/p.$$

In plotting the overall transfer function (Fig. 11) a gain K_6 of 10^{-6} in k per second/°C has been assumed. Some variation of K_6 (perhaps a factor of 2: 1) would be expected due to variation of control-rod effectiveness with position in the reactor.

Discussion

Considering the overall open-loop frequency diagram, Fig. 11, it would appear that the loop gain could be increased (perhaps by 20 dB) without risk of instability. The most effective way of changing the loop gain is by varying K_6, the control-rod gain term. The value assumed was 10^{-6} per second/°C. Control-rod speed has an effect on the safety of the system as was explained earlier, and for comparison, the speed required to

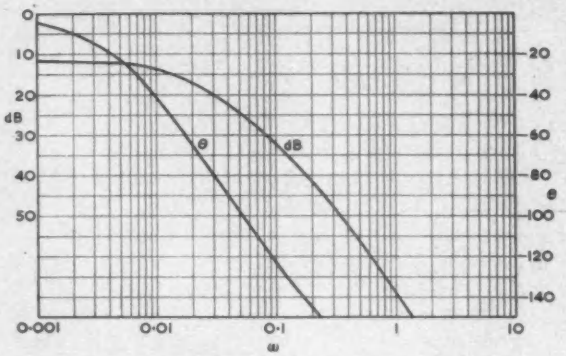


Fig. 9 Frequency diagrams for $K_4G_4 = T_1/T_{1(error)}$. $K_4G_4 = 0{\cdot}26/(1 + 8{\cdot}8p)(1 + 80p)$

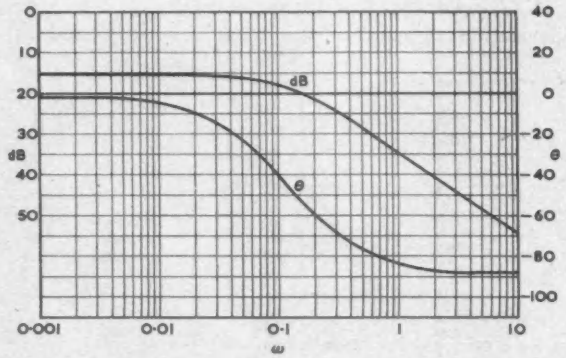
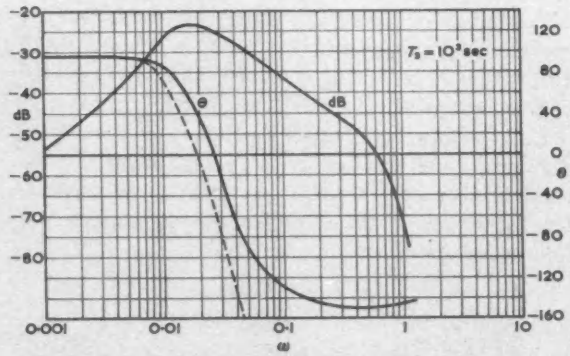


Fig. 10 Frequency diagram for $K_5G_5 = T_1/T_2$. $K_5G_5 = 0{\cdot}167/(1 + 8{\cdot}8p)$



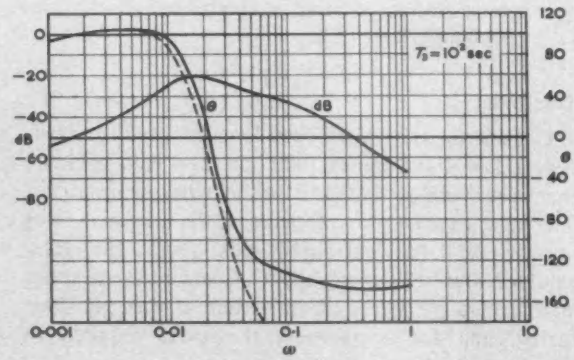


Fig. 11 (above and below) Overall open-loop transfer function

meet the normal self-induced reactivity changes is of order 5 10^{-6} in k per second. A controller could be designed with the assumed value of K_6 (10^{-6} per sec/°C) over a range of ± 5°C, and beyond this range to saturate. Keeping within the control-rod speed-range which is otherwise necessary, the controller would not decrease the safety margin of the reactor. However, if the gain were increased five-fold, a linear range of ± 1°C would no longer be reasonable—stabilization within 1°C would be unlikely and the controller would apparently function in an on-off fashion. This might give satisfactory results but the analysis required would, of course, be different from that presented here. In the case where the moderator-side capacity has been reduced to 10^2 sec, the natural gain of the system is improved around the frequency (·02 rad/sec) at which phase lags increase rapidly. Thus there are advantages to safety in improving the system response by favourably changing its inherent characteristics as much as possible, rather than in correcting a bad system by suitable feedback.

In the derivation of K_5G_5, a time constant was introduced to represent the mixing of the coolant in the reactor coolant header. Transport lags also occur owing to the flow of coolant from reactor to steam-raising unit and back. Some of these delays may be represented as occurring at the position K_7G_7 in Fig. 2 and may thus be combined simply in series in Fig. 11. The effect is to add a phase lag θ_D; if the time lag is τ sec, at any angular frequency ω,

$$\theta_D = \frac{\tau\omega}{2\pi} \times 360°.$$

Assuming a value of τ of 200 sec, the effect on phase angle is shown by the dotted line in Fig. 11. The highest controllable frequency is seen to be critically dependent upon the transport lag τ. This will often be determined by such factors as the need for flexibility in gas ducts, requiring a certain minimum length and thus (in conjunction with economic pumping powers) a minimum transport lag. However, by similar analysis the advantages of promoting mixing, as opposed to pure transport lag, may be explored; and phase-correcting networks, linked perhaps to blower speed, may be devised.

References

1. Bowen, J. H.: 'Automatic Control Characteristics of Thermal-Neutron Reactors', *J.I.E.E.*, Paper No. 1432M—December 1952.
2. Bowen, J., and Masters, E. F. O.: 'Temperature transients in gas-cooled thermal-neutron reactors', *J.I.E.E.*, Paper No. 2422M—October 1957.
3. Miida and Hara: 'Analysis of Dynamic Characteristics of British type reactors', *JAERI*, 1006.B, June 1959.
4. Takahashi, Y.: 'Transfer function analysis of heat exchange pressure', *D.S.I.R. Conference on Servomechanisms*, 1950.

NEXT MONTH

The third article in the series will be 'Control mechanisms for nuclear reactors' by J. Tindale, M.I.Mech.E., of Elliott Bros. (London) Ltd.

A monthly review—under basic headings—of the latest control engineering developments for all industries; specially edited for busy technical management, plant and production engineers, chemical engineers, etc., who are not specialized in instrument and control systems

IDEAS APPLIED . . .

. . . to SPEED

Force-balance transmitter

A new speed transmitter introduced by the Cambridge Instrument Company has been developed principally for measuring the ram speed of extrusion presses. A difficulty in this application is that the speed of the working stroke is very low compared with the speed of the return stroke; consequently a conventional device—such as a direct-geared tachometer—is likely to suffer damage in the mechanical transmission.

In the Cambridge equipment, an electromagnetic force-balance system produces a current output proportional to speed. Part of this system also acts as a magnetic coupling to absorb transmission shocks.

The principle of the transmitter is shown in Fig. 1.1. Movement of the ram is converted to rotary motion by a steel tape running on the pulley *P*. One end of this tape is connected to the ram, tension being maintained by counterweights attached to the other end. Connected to the same shaft as the pulley is the wheel *W* carrying two or more magnets *M*.

The rotation of these magnets produces eddy currents in an aluminium disk *D*, which consequently tends to follow the motion of the wheel *W*. The disk *D* carries with it a coil *G* and a shutter *S*. The direction of rotation of *D* produced by the extrusion stroke is such that the shutter *S* moves to allow light from a lamp *L* to fall on the photo-transistor *T*. The signal produced by the photo-transistor is fed to an amplifier *A*, which sends a proportional signal via the coil *G* to the indicating and recording instruments. Being suspended between magnetic poles, the coil *G* exerts a torque on the disk *D* which opposes that produced by the eddy current effect. An equilibrium position is established between these opposing torques, the output current being proportional to the speed of rotation of *P*.

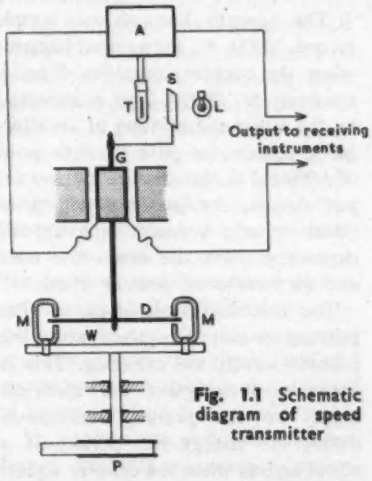


Fig. 1.1 Schematic diagram of speed transmitter

On the return stroke of the extrusion ram, the coil and disk assembly is prevented by a mechanical stop from following the rotation of the lower magnet assembly. It is held in a position where no light is allowed to fall on *T*, and consequently there is no output signal.

. . . to DATA HANDLING

Multi-channel event recorder

R. L. GREGORY, M.A., *Cambridge University*

Data recorders generally employ a continuous feed for the record paper, with some system for marking the paper when an event occurs; the time of occurrence of each event can then be found by measuring intervals along the record paper. The continuous drive provides the time-base in a simple manner, but if small time intervals are to be discriminated a high drive speed is required, which gives high running cost and requires large storage space if the records are to be kept over long periods. The machine to be described is rather more complicated than polygraph recorders of this kind, but it provides a more convenient record, and has the great advantage that the record paper is stationary in the absence of input signals. The running costs are therefore low, and time and labour needed to read the record are reduced. The machine is portable and inexpensive; it employs standard electromechanical components, and servicing is possible without special knowledge of electronics.

The time-base is digital, and is provided by a cyclometer counter fitted with type-face. This is driven at a constant rate by a small synchronous motor, the rate depending upon the time discrimination required. A count rate of either one or ten counts/sec is entirely feasible with available small printing counters, and it may be possible to achieve a count rate of 100 counts/sec—giving a time discrimination of 0·01 sec—with the latest nylon wheel counters. At present the best time discrimination is to the nearest 0·1 sec, the count rate being ten counts/sec.

If there were one type of event only, the counter alone would serve to indicate the times of occurrence, the signals being used to initiate the opera-

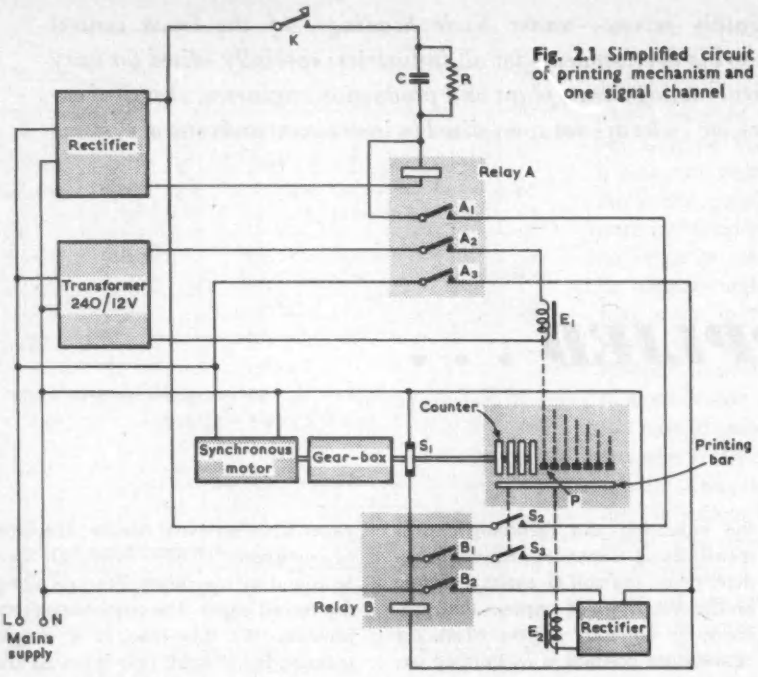


Fig. 2.1 Simplified circuit of printing mechanism and one signal channel

tion of a printing mechanism. In this machine, the counter is made to record the time of occurrence of signals arriving on a number of channels, each being identified by a letter symbol. The final record looks something like this:

1011	a
1138	b
2990	ab
3421	c
7955	ef
9532	a c f
0000	*
1228	b

The following features may be noted:

1. The numbers indicate time of occurrence of signals arriving on any channel, the channel being identified by its letter symbol.
2. Time intervals may be determined by subtracting the earlier from the later time, the units being determined by the count-rate used.
3. The record is closely packed, the paper being stationary except immediately after a print, when it moves a small fixed amount ready for the next print.
4. Any number of channels may print together. This is an important feature: it leads to a simple circuit, since there is no problem of signals piling up waiting to be printed, and combinations of letters can be used to extend the number of effective channels.
5. The seventh line of the sample record, '0000 *', shows what happens when the counter completes a cycle, returning to '0000'. This is indicated by the automatic printing of an asterisk in conjunction with the time print of '0000'. In the absence of any input signals, the machine will print '0000 *' at a constant interval, this depending upon the count-rate used and the number of counter wheels.

The machine is designed so that printing cannot take place while the counter wheels are changing. This is done by interrupting the electrical supply to the printing mechanism during the change-over period. If a signal arrives when the counter wheels are rotating, it is stored by a self-holding relay in its channel circuit until the count wheels have stopped at their next printing position. Printing then takes place.

The method of operation may be seen from Fig. 2.1, which shows the circuit for one channel. The occurrence of an event closes the contact K, which applies a transient voltage across the operating coil of the relay A. This is sufficient to operate the relay, which is then held in by a circuit through the contact A_1 and the switch S_2. This arrangement ensures that only the start of the signal is recorded, but that the relay A is held in long enough to perform the printing operation (i.e., until S_2 is broken).

Relay contacts A_2 and A_3 control the movement of the printing mechanism through the solenoids E_1 and E_2. E_1 brings the channel print symbol P into position, while E_2 operates the printing bar. This bar presses the record paper and the ink-ribbon against the counter type-face and any channel symbols positioned for printing. To avoid printing when the counter numbers are changing, the energizing circuit for E_2 is broken by the contact B_2 of relay B during the change-over period. This is achieved by taking the supply to relay B through the rotary switch S_1, which is geared to the counter. Any channel signal arriving during the change-over period is held up until the next counter number is in position.

When the printing action has started, relay B is held in by the circuit through B_1 and S_3. This ensures that the event is printed, even if S_1 opens during the printing stroke. (Hence S_1 must break sufficiently early to allow time for printing before the change-over starts). At the instant of printing, the microswitches S_2 and S_3 are opened by the motion of the printing bar. S_2 breaks the hold-on circuit for relay A, thus preventing the event being recorded more than once; S_3 breaks the hold-on circuit for relay B, so that if a second event occurs after the start of the printing stroke, and S_1 is open, this second event will be held up until the counter change-over is complete.

The parts A, C, R, K and E_1 of the system are duplicated for the other signal channels, the remainder of the system being common to all channels.

Motion of the paper chart and the ink-ribbon is produced by ratchet mechanisms, the movement being initiated by the printing bar on its return stroke. The chart thus moves a fixed distance forward after recording each event (or group of events).

This recorder was originally developed in the Psychological Laboratory at Cambridge University for recording human and animal responses, but it is expected to have many industrial uses. It was manufactured for a short time by Mr John Russell, the development engineer being Mr J. Sutton, who deserves much credit for his work. Further development is now being carried out at Cambridge, with support from the D.S.I.R., and it is hoped that it will shortly be made

available under the auspices of the N.R.D.C. It is described in, and protected by, British Patent No. 836,111 and U.S.A. Patent No. 2,944,867.

. . . to TEMPERATURE

Tape slide-wire for self-balancing digital indicator

A potentiometric temperature indicator introduced by B & H Instruments* departs from the normal practice of using a toroidal-coil arrangement for the slide-wire. The wire, in the form of a single uncoiled strand, is bonded to the edge of a vulcanized-fibre tape, which is perforated to run on a taper-tooth sprocket geared to the counter mechanism. The tape, driven by the sprocket from a conventional servo-system, runs between two storage spools, the pick-off contact being situated between them.

This arrangement has several advantages: the relative movement between the wire and the pick-off contact is greatly increased for a given voltage drop, thus decreasing the effect of any inaccuracies which might be introduced by gearing between the slide-wire and the digital indicating mechanism; assuming 'point' contact, the system has theoretically infinite resolution; wear on the slide-wire is even, and should be less than that of a similar conventional slide-wire.

An overall accuracy of the order of 0·1% of full range is claimed for this measuring system. The calibration procedure used compensates for non-linearities in the input by varying the centre-distance of the holes in the tape. This variation causes the tape to lead or lag the nominal peripheral travel of the driving sprocket. It is claimed that this method of correction is successful for deviations of up to 13% from a linear law.

**Marketed in the U.K. by Bryans Aeroquipment*

. . . to POSITION

Stabilization of control systems with backlash

E. A. FREEMAN, B.Sc., Ph.D., *Sunderland Technical College*

The presence of backlash in automatic control systems adversely affects the dynamic characteristics of the system. In some cases sustained oscillations of the output may result, whilst in others the transient response may become excessively oscillatory. Positional accuracy is also impaired unless all of the reset is taken from the output side of the backlash—an action which results in a less stable system. Mechanical wear is increased appreciably, as during each cycle of an oscillatory transient there is an impact between the driving member and the driven member.

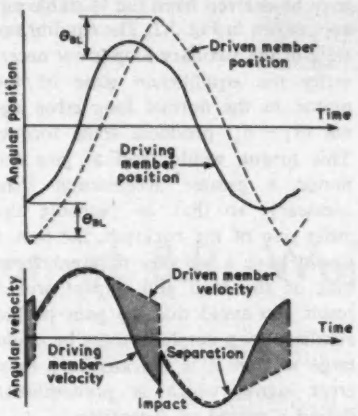


Fig. 3.1 Responses to a sinusoidal input of driving and driven members in a control system with backlash

Fig. 3.1 shows the wave-form obtained when the output position is required to follow a sinusoidal input signal. The discontinuities in the velocity wave-form indicate an impact between the driving and driven members, and the shaded area, being equal to the angle of backlash, θ_{BL}, defines the period for which the two members are not in contact through the gearing. The position wave-form shows that the output member lags behind the driving member and this lag aggravates instability. Both the impact and the lag increase in magnitude as the period of separation increases.

To improve the performance therefore it becomes necessary to reduce the period of separation whilst also reducing the differences between the velocities of the two members when contact is made. These results may be achieved by an auxiliary control loop which is switched into operation only for the period of separation. This loop is arranged to control the difference between the driving member position and the driven member position with a dead-beat transient response. In this way the driving member can be made to move to the correct side of the backlash, in a controlled manner, whenever the two members tend to separate. Further, because the auxiliary loop is arranged to have a dead-beat response the two members come into contact with zero relative velocity and impacts are thereby avoided. If in addition the natural frequency of this loop is made very high, by using a high-gain amplifier, then the period of separation and hence the lag will be considerably reduced.

Fig. 3.2 shows a block diagram of the arrangement applied to a motor driving a gear-box which has a ratio of N:1 and suffers from backlash. The symbols θ_m and $\dot{\theta}_m$ respectively represent the angular position and angular velocity of the motor; similarly, θ_o and $\dot{\theta}_o$ represent the position and velocity of the output shaft.

Whenever the motor and load tend to lose contact, say because the motor starts to decelerate more quickly than the load, the signal $\dot{\theta}_m/N$ differs from the signal $\dot{\theta}_o$ and the bi-stable circuit switches to produce a constant output voltage whose sign depends on the sign of $(\dot{\theta}_m/N - \dot{\theta}_o)$. The switching action of the bi-stable circuit triggers a mono-stable circuit which produces a pulse of duration equal to the time taken by the motor to traverse the backlash. This pulse is fed to a relay (or an electronic gate)

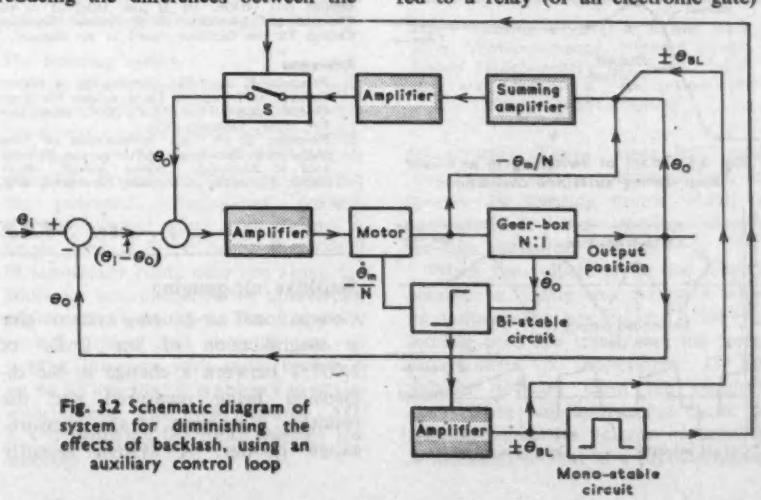


Fig. 3.2 Schematic diagram of system for diminishing the effects of backlash, using an auxiliary control loop

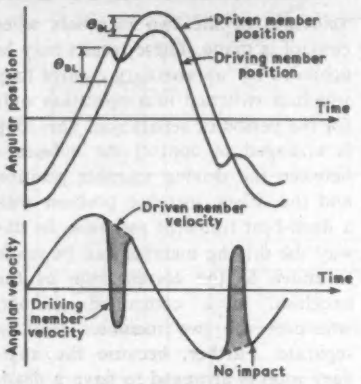


Fig. 3.3 Responses to a sinusoidal input of the stabilized control system

which connects the auxiliary loop signals into the system for the predetermined transit time. The auxiliary loop error signal is made up of a difference signal $(\theta_m/N - \theta_o)$ and a signal of size θ_{BL}, the angle of backlash, whose sign changes whenever the motor and load lose contact. Consequently the auxiliary loop is in equilibrium when $(\theta_m/N - \theta_o) = \pm\theta_{BL}$.

This condition obtains with the motor on one side of the backlash. The side of the backlash to which the motor moves after it has lost contact depends on the sign of the signal θ_{BL}. However, since the side of the backlash to which we require the motor to move depends entirely on the sign of $(\dot{\theta}_m/N - \dot{\theta}_o)$, the appropriate signal may be derived from the bi-stable circuit shown in Fig. 3.2. The equilibrium state of the auxiliary loop is not necessarily the equilibrium state of the motor, as the normal loop error signal $(\theta_i - \theta_o)$ produces some torque. This torque would tend to give the motor a greater acceleration than necessary, so that on reaching the other side of the backlash, the motor would have a velocity different from that of the load and impact would result. To avoid this the gain of the auxiliary loop amplifier must be made large so that it is the auxiliary loop error signal which is predominant during a period of separation.

Impacts would also result if the transient response of the auxiliary loop alone exhibited overshoots, for the motor cannot exceed the auxiliary loop equilibrium position, $\theta_m/N = \theta_o \pm \theta_{BL}$, without colliding with the load. A dead beat response can be obtained, however, by including a suitable stabilizing network. The design of this network is not straightforward because, in view of the high gain used, the servo-motor overloads during the transient. A full analysis of this problem is given elsewhere (*1, 2*).

The effect of the stabilizing technique is illustrated by the wave-forms of Fig. 3.3. Comparison with Fig. 3.1 shows that the period of separation is greatly reduced and that the impact is almost eliminated.

Fig. 3.4 compares the transient responses obtained before and after stabilization whereas Fig. 3.5 illustrates how sustained oscillations normally obtained with systems having backlash may be quenched by switching the auxiliary loop into operation.

Fig. 3.4 Transient response of control system to a step input: (a) without auxiliary loop; (b) with auxiliary loop

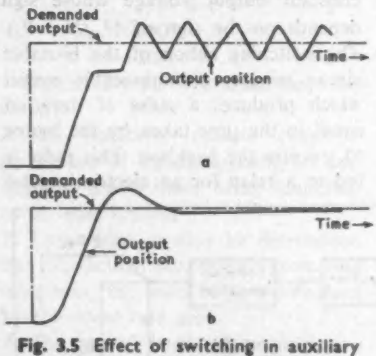
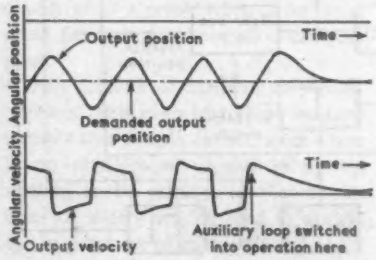


Fig. 3.5 Effect of switching in auxiliary loop during sustained oscillations



Acknowledgement

The author wishes to acknowledge the Institution of Electrical Engineers for giving permission to publish this article. He is also indebted to the Principal and Governors of Sunderland Technical College for the facilities placed at his disposal.

References

1. Freeman, E. A. 'The Stabilization of Control Systems with Backlash Using a High Frequency On-Off Loop', *Proc. I.E.E.*, Pt.C. Monograph No. 356M., February 1960.
2. Freeman, E. A. 'An Investigation of Some Non-Linear Phenomena Affecting the Performance of Automatic Control Systems,' Ph.D. Thesis, University of Durham, November, 1958.

. . . to SIZE

Sensitive air-gauging

Conventional air-gauging systems give a magnification of the order of 5,000:1 between a change in the dimension being measured and the resulting movement of the pressure-gauge pointer. A system recently patented by Thomas Mercer Ltd produces further magnification by applying the output signal from a conventional system to a Bourdon tube, the movement of which obturates a second air nozzle.

Referring to Fig. 4.1, the air supply is reduced to the appropriate pressure by the reducing valve V, and is taken to the nozzle N_1 via the restriction R_1. This part of the system is conventional, N_1 being directed at the surface being gauged, and the pressure in the nozzle line giving a measure of the clearance between N_1 and the surface. Instead of being taken directly to the measuring gauge, this pressure is applied to the Bourdon tube B, the movement of which varies the clearance between the block C and the second nozzle N_2. This nozzle, which is in series with the restriction R_2,

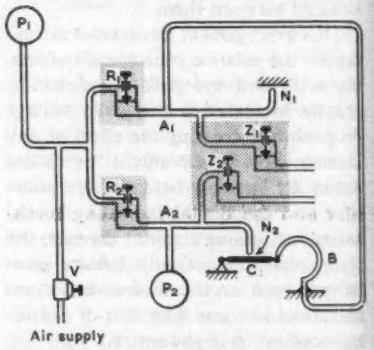


Fig. 4.1 Pneumatic connections of sensitive gauging system

uses the same regulated air supply as the primary system. The final reading is taken from the gauge P_2.

The practical system differs in some ways from the schematic arrangement of Fig. 4.1: a three-way tap is incorporated to enable the gauge P_2 to indicate the pressure at either A_1 or A_2, depending on whether a 'coarse' or 'fine' response is required; the block C is arranged to slide across the top of the nozzle N_2, rather than approach it as in the diagram, the nozzle having a cross-section designed to give the required pressure/movement characteristic. The restrictions R_1 and R_2 may be varied to alter the pressure-range over which the respective nozzles operate, and variable bleeds, Z_1 and Z_2, provide zero adjustments.

INTEGRATION: *With reference to the description of the Honeywell integrator published in last month's* Ideas Applied, *we have been asked to point out that the special d.c. motor used in this system is manufactured by Electro Methods Ltd, and not, as might be supposed from our description, by Honeywell Controls.*—EDITOR.

Robotug installation at B.R. Wolverhampton

E.M.I. driver-less tug system enables British Railways to move a larger tonnage for less effort

THE E.M.I. ROBOTUG SYSTEM OF DRIVER-less trucks for goods handling is fast entering industry as an accepted tool, and *Control* was able to see one of the first installations in operation recently. This was at the Wolverhampton, Herbert Street, Goods Station of British Railways, Western Region, where five Robotug vehicles are now working on inwards goods handling. The Wolverhampton scheme follows from two years' collaboration between E.M.I. Electronics and British Railways, and the experimental operation of two Robotugs at Newton Abbot Goods Shed.

Basically, each Robotug, together with its trolleys, is caused to follow an induction wire guidance system, which consists of a single alternating-current-carrying wire laid along the required route or routes. At Wolverhampton the Robotug track layout is U-shaped and goes round two wagon platforms consisting of three sections of eight wagons on Number 1 Road, and two sections of twelve wagons on Number 2 Road—48 wagons in all.

Each tug incorporates a program unit which controls the selection of routes in accordance with a pre-arranged sequence of halts. The Wolverhampton scheme has twelve such programmed halts, five being homing stops for each of the five tugs, and the remaining seven, cartage and transfer points.

Work commences at 6 a.m. The Robotugs, which are battery-powered, are taken off charge and walked, or driven in conventional fashion, to a spur on the main goods platform. The homing switch is operated and the tugs proceed to their individual stops. Porters unload the wagons, and checkers sort the goods and load the particular trolleys for the various cartage and transfer stops. The checker then operates a three-position pendant switch above the waiting tug, and the latter reverses along the wagon-discharge line and couples automatically with the train of trolleys. The tug is then programmed in accordance with trolley-loading and is sent on its way, halting automatically at the programmed cartage and transfer posts.

When tug and trolleys halt at a programmed stop, the cartage checkers detach their trolleys and replace them with empty trolleys, and the tug-and-trolley train proceeds to the next programmed stop, and so on until all loaded trolleys have been replaced by empties. The Robotug and its train then returns to its own stop in the lay-by, and the process is repeated.

This is the basic arrangement, but the Wolverhampton scheme is rather more complex, various refinements having been incorporated in order that the five trains of tugs and trolleys may be used to the best advantage. For example, a loop line is incorporated so that an empty Robotug train should not have to complete the full circuit around both platforms unnecessarily.

The Robotug system

The Wolverhampton scheme employs modified Conveyancer-Scott tugs, but *Control* understands that any similar tug may be used. The induction guidance system operates by making the powered vehicle—tug, trolley, truck, or what have you—follow a single wire, laid just below floor level (a temporary route may run along the surface), which carries an alternating current of about 0·1 A. The frequency is not critical but it must not, of course, interfere with radio reception or be so low that it is subject to mains interference. For these reasons, 2000 c/s is probably the most suitable frequency.

The magnetic field produced around the wire induces voltages into sensing coils at the front of the truck. It can be seen on referring to Fig. 2 that these voltages are amplified in two-stage transistor amplifiers. The resulting signals are rectified and caused to energize relays operated by bi-stable trig-

Fig. 1 Loading a trailer at British Railways' Wolverhampton, Herbert Street, Goods Station where five E.M.I. Robotugs are used in a new system for inwards goods handling

ger circuits. These 'steer left' and 'steer right' relays operate in turn to reverse the steering motor which is connected to the steering wheels through reduction gearing.

When the vehicle is on the correct course, i.e. along the guidance wire, the voltages that are induced in the two sensing coils are small, and the steering control is inoperative. If the vehicle deviates from the required course, one coil approaches closer to the wire and the voltage induced in it increases so that at a predetermined

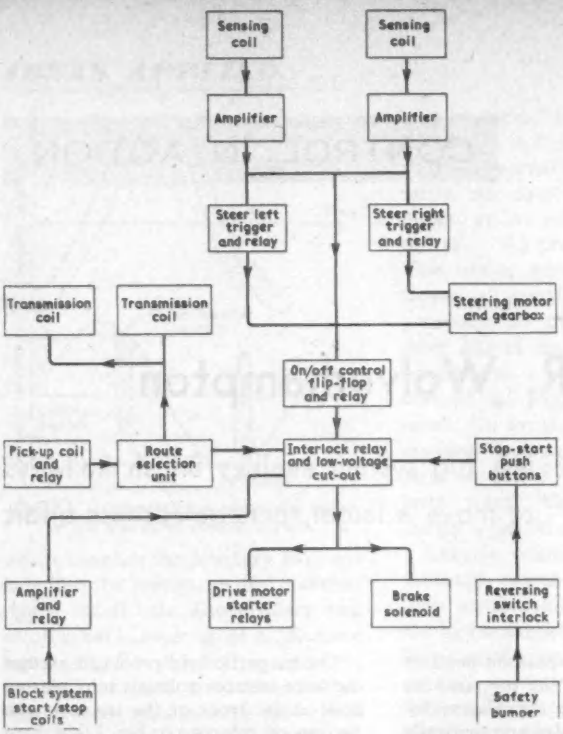


Fig. 2 Voltages induced in the two sensing coils by the magnetic field around the guidance wire, are arranged to control a steering motor. Various safety devices are incorporated

level it will be sufficient to operate the steering gear to turn the vehicle back on course. When this happens, the coils are equidistant from the wire and the steering motor is inoperative.

Fig. 2 also shows that a signal, which is the sum of those from the two amplifiers, is fed to a further flip-flop and an on/off control relay. This circuit is so designed that when the proper current is flowing through the induction wire, the relay will operate to release the brakes and energize the main-drive-motor starter-relays. If the current through the wire should fail, or the vehicle wander unguided off course, the starter relays are de-energized and the brakes applied.

A safety interlock system is incorporated, the contacts of a low-voltage cut-out and interlock relay being in series with the contacts of the on/off control relay (Fig. 2). The former relay will operate only if (a) the battery voltage is above 21·5 V, (b) the microswitches (which are held open when the bumper of the truck is touching an obstruction and so de-energize the relay and halt the truck) are closed, (c) the reversing control is in neutral or 'forward', and (d) the 'start' button has been depressed. If any of these conditions do not apply, the truck cannot be started, or, if it is running, the drive motor will be de-energized and the brakes applied.

Block control and routing

At Wolverhampton the guidance track is divided into sections or blocks as in railway practice, so that a number of vehicles may operate on a variety of routes. This means that only that section of the track over which a vehicle is passing, or about to pass, is energized, and a 'dead' block exists between any two vehicles.

Consider blocks *A*, *B*, *C* etc. Block *A* is energized and a vehicle is proceeding towards block *B*. Each vehicle carries an oscillator feeding a transmission coil, and as the vehicle passes through block *A* this coil interacts with a pick-up or sensing coil, *Z*, on the track. The voltage induced in the sensing coil operates relay *RLSB*, in Fig. 3, which is held on by *RLSB1*. For the vehicle to enter block *B*, block *C* must be 'dead'—no vehicle in that section. If so, *RLC4* will be closed, operating *RLB* via *RLSB2* and self-holding via *RLB1*. As *RLB* operates, *RLSB* is de-energized via *RLB2*, *RLB3* closes to energize block *B*, and *RLB4* opens to de-energize *RLA* and block *A*.

If, however, block *C* carries a vehicle, its track is energized. *RLC4* will be open circuit and although *RLSB* will operate (storing the information that a vehicle is waiting to enter block *B*) *RLB* is inoperative and block *B* 'dead'.

Yet a further coil, *LA*, is set in the floor and this is energized as *RLB* is de-energized. As the vehicle passes over coil *LA* a pick-up coil operates the interlock relay circuit to halt the vehicle. It follows that if block *C* is clear (*RLC4* closed) block *B* will be energized and the vehicle will proceed, but if block *C* is occupied (*RLC4* open) the vehicle will be halted on passing coil *LA*. The arrangement is such that as soon as block *C* is clear, *RLC4* will close to energize block *B*, and a 'start' coil on the vehicle has a voltage induced in it which, suitably amplified, re-energizes the interlock relay.

Similar arrangements of transmission and sensing coils enable the vehicles to perform a more complex variety of manœuvres.

Route selection

Destination and route selection may be either for single-destination or, as at Wolverhampton, multiple-destination working. Basically the arrangement depends on the interaction of coils fixed in the track with a pick-up coil on the vehicle which controls a relay to operate a counting mechanism as each coil is passed. A program is patched into a board on the vehicle.

Other users

British Railways appear to think highly of the Wolverhampton system, which is in fact the second Robotug installation of any importance. The first was a two-Robotug scheme for Huta Florium, a Polish steel works. A very large scheme for Guest, Keen and Nettlefolds is nearing completion; forty Robotugs will be employed moving stores both in and out. A single Robotug installation for J. Lyons & Co., Greenford, is also of interest. They will use a two-ton vehicle to carry coffee, and as the Robotug will have to cross factory roads, such refinements as automatic traffic signals are being incorporated. Yet another user is the Rootes Group, which is having a two-Robotug pilot scheme installed at Coventry.

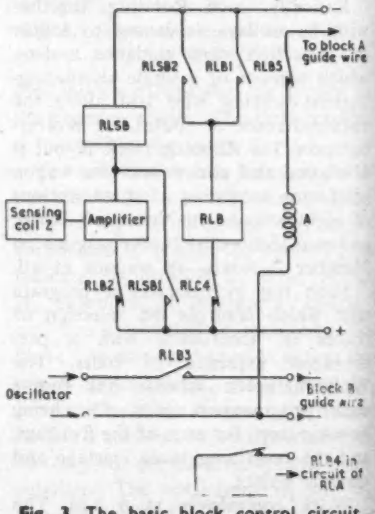


Fig. 3 The basic block control circuit provides a 'dead' section between each vehicle and any other vehicle

Several other potential users have shown interest. These include a British Railways goods yard in the Portsmouth area, Vauxhall Motors, Fisons at Manchester, Heinz at Harlesden, and Hepworth and Grandage of Bradford.

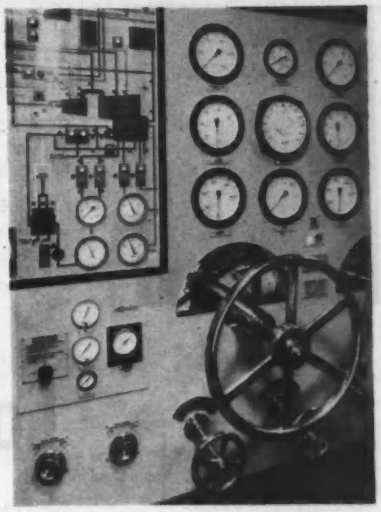
Exhaust control in 'Windsor Castle'

The 38,000-ton Union-Castle vessel, R.M.S. *Windsor Castle*, which sailed on her maiden voyage on the South African mail service recently, has on board an automatic pneumatic control system designed by the Instrumentation Division of Associated Electrical Industries. The control system maintains pressure in the auxiliary exhaust steam range at a constant value, thus appreciably improving fuel economy. A.E.I. systems of this type are in use in several modern British naval vessels, and a similar arrangement by Fisher Governor in British Petroleum's tanker *British Queen* was described in these columns in June 1960.

In *Windsor Castle*, exhaust from the turbine-driven feed pumps discharges into the auxiliary range and is led to a large de-aerator feed heater which, for optimum efficiency, must be supplied with steam at constant pressure. The pressure is maintained within ± 1 lb/in^2 either by dumping steam to the main condensers or by introducing low-pressure turbine pass-out steam. If the latter is inadequate to maintain the desired exhaust pressure it is supplemented with high-pressure de-superheated live steam.

The exhaust control system operates on air signals in the range 3 to 15 lb/in^2. Pressure in the auxiliary exhaust range is taken from a sensing point to a pressure transmitter which converts it into a pneumatic signal. This signal is fed to a controller in which it is compared with the desired pressure. Any deviation causes the controller to produce an output signal proportional to the difference and this operates the valve positioners of either the reject or the supplementary valves.

It is impossible for the condenser dump valves to be open at the same time as either of the supplementary valves, so the live steam cannot be rejected to the condenser. Additionally, interruption of the controller's air supply causes the control valve to 'fail safe', so that the condenser dump valve closes, the low-pressure turbine pass-out valve opens, and the high-pressure steam valve closes.



Control panel in the engine room

LOOKING AHEAD

Unless otherwise indicated, all events take place in London. B.C.S. British Computer Society. Brit.I.R.E. British Institution of Radio Engineers. I.E.E. Institution of Electrical Engineers. I.Mech.E. Institution of Mechanical Engineers. R.Ae.S. Royal Aeronautical Society. S.I.T. Society of Instrument Technology.

FRIDAY 7—SATURDAY 8 OCTOBER
Aviation Electronics and its Industrial Applications. Bristol College of Science and Technology. Registration: Hon. Secretary, South Western Section, Brit.I.R.E., c/o The School of Management Studies, Unity Street, Bristol, 1.

TUESDAY 11 OCTOBER
A brief survey of *The Principles of Automatic Control* by G. Heywood. 7.00 p.m. Borough Polytechnic. Details: G. L. H. Bird, Borough Polytechnic, London, S.E.1.

THURSDAY 13 OCTOBER
Transistor switches in monitor and control systems by W. A. Ross. S.I.T.

TUESDAY 18 OCTOBER
A repeat of *The Principles of Automatic Control* by G. Heywood. (See Tuesday 11 Oct.)

TUESDAY 18—FRIDAY 21 OCTOBER
First Effluent and Water Treatment Exhibition and Convention. Seymour Hall, Thunderbird Enterprises Ltd., 140 Cromwell Road, London, S.W.17.

WEDNESDAY 19—WEDNESDAY 26 OCTOBER
Interkama International Congress and Exhibition for Instrumentation and Automation, Düsseldorf.

TUESDAY 25 OCTOBER
Pneumatic Instruments in Process Control by N. Robertson. 7.00 p.m. Borough Polytechnic. (See Tuesday 11 Oct.)

A new method of strip speed measurement using random waveform correlation by Messrs. Butterfield, Bryant and Dowsing. S.I.T.

Computers and their application in chemical engineering by D. W. Holman and J. J. Settle. 6.30 p.m., Manchester College of Science and Technology. Details: A. V. Bailey, 2 Finney Drive, Wilmslow, Ches. (I.Chem.E.)

WEDNESDAY 26 OCTOBER
Industrial applications of an automatic control using electronic techniques by R. J. F. Howard. 7.15 p.m., Electrical Engineering Dept., Birmingham University. Brit.I.R.E.

Radio aids for automatic landing developed by the Blind Landing Experimental Unit by J. S. Shayler. 7 p.m., School of Management Studies, Unity Street, Bristol. Brit. I.R.E.

TUESDAY 1 NOVEMBER
Automatic Control of Operations and Processes in the Ford Thames Foundry by K. H. Lee. 7.00 p.m. Borough Polytechnic. (See Tuesday 11 Oct.)

TUESDAY 8 NOVEMBER
Electronics in Process Control by C. G. Seeds and W. Barber. 7.00 p.m. Borough Polytechnic. (See Tuesday 11 Oct.)

WEDNESDAY 9 NOVEMBER
A shaft position digitizer using synchros by T. Roberts. 7 p.m. S.I.T.

TUESDAY 15 NOVEMBER
Automatic Control of Machine Tools by J. W. Smith. 7.00 p.m. Borough Polytechnic. (See Tuesday 11 Oct.)

THURSDAY 17 NOVEMBER
The control of a single effect concentrating evaporator — dynamic characteristics and analogue computer study by F. P. Lees, L. W. A. Glasson and J. A. Anderson. 7 p.m. S.I.T.

MONDAY 21—WEDNESDAY 23 NOVEMBER
International seminar on *Analogue computation applied to the study of chemical processes*, Brussels. Details: R. Vichnevetsky, 43 rue de la Science, Bruxelles 4, Belgium.

TUESDAY 22 NOVEMBER
Automatic Control of Boiler House Plant by P. J. Wheeler. 7.00 p.m. Borough Polytechnic. (See Tuesday 11 Oct.)

TUESDAY 22—THURSDAY 24 NOVEMBER
Conference on electronic telephone exchanges. I.E.E.

TUESDAY 29 NOVEMBER
Automatic Control in the Steel Industry by M. H. Butterfield. 7.00 p.m. Borough Polytechnic. (See Tuesday 11 Oct.)

Symposium on nuclear temperature scanning. *Temperature scanning equipment for a large nuclear reactor* by C. Hall. 7 p.m. S.I.T.

Temperature scanning equipment for use in a nuclear power station by A. G. Blay, P. G. Davey and F. C. Flint. 7 p.m. S.I.T.

TUESDAY 13 DECEMBER
Analytical instrumentation of process gas streams by J. C. Hawkes. 7.30 p.m. Blossoms Hotel, Chester. Details: A. V. Bailey, 2 Finney Drive, Wilmslow, Cheshire. (I.Chem.E.).

WEDNESDAY 14 DECEMBER
Speed control of Aircraft Gas Turbines for jet propulsion by R. J. Walsh and R. W. Haigh. 7 p.m. S.I.T.

LOOKING FURTHER AHEAD

MONDAY 9—WEDNESDAY 11 JANUARY 1961
7th National Symposium on Reliability and Quality Control. Bellevue-Stafford Hotel, Philadelphia, Pa., U.S.A.

TUESDAY 31 JANUARY 1961
Instrumentation Past, Present and Future by L. S. Yoxall. 7 p.m. S.I.T.

WEDNESDAY 15—FRIDAY 17 FEBRUARY 1961
1961 International Solid-state Circuits Conference. University of Pennsylvania and the Sheraton Hotel, Philadelphia, Pa., U.S.A.

MONDAY 27—FRIDAY 31 MARCH 1961
3rd National Symposium on Temperature. Its Measurement and Control in Science and Industry. Columbus, Ohio.

TUESDAY 9—WEDNESDAY 17 MAY 1961.
International Exhibition of Measurement, Control, Regulation and Automation (Mesucora) and 58th Exhibition of French Physical Society, C.N.I.T., Paris. Secrétariat Général, 40, rue de Colisée, Paris, 8.

MONDAY 26 JUNE—SATURDAY 1 JULY 1961
International Measurements Conference, (Imeko), Budapest. Details: Prof. J. F. Coales, Cambridge University, Trumpington St., Cambridge, or Imeko Secretariat, Budapest 5, P.O.B. 3.

This news-letter from our special correspondents in the United States reports an important meeting of control engineers held at M.I.T. last month

Look at America

This month: J.A.C.C. début—self-optimization—chemical processes—U.S.A. v. U.S.S.R.

J.A.C. Conference makes it début

The first fully co-ordinated, jointly sponsored control conference in the United States was held September 7 to 9, 1960, at M.I.T. General Chairman W. D. Archibald (Energy Control Co., N.Y.C., N.Y.), who had the major responsibility for this A.S.M.E -organized conference, announced that total registration came to 725. Several members of the Boston Section of A.S.M.E. and members of the M.I.T. staff worked tirelessly as hosts to the visitors from all parts of the U.S.

The program, which was organized by Dr J. M. Mozley (Johns Hopkins Hospital, Baltimore, Md.), included 56 technical papers, a comprehensive report on the Moscow Ifac Congress,* and a panel discussion on automatic control education. As in the case of the Moscow congress, adaptive and self-optimizing systems received a lot of attention. Optimal design of saturating systems, computer control systems and non-linear systems were also of great interest. A rough break-down is as follows: *Adaptive and self-optimizing*, twelve papers; *Computer control*, seven papers; *Non-linear systems*, six; *Optimal switching*, four; *Control components*, ten; *Dynamic measurements*, five; *Chemical process dynamics*, three; *Pneumatic systems*, two; *Control of nuclear systems*, two; and *General*, five.

The highlights which your reporters were able to see are given below.

Adaptive and self-optimizing systems

One of the most exciting and promising new concepts to appear in the field of automatic control within the last decade is the adaptive control principle. In the words of J. H. Westcott†—'It is, so to speak, the popular thing of the moment, and not to have views about it is inadmissible.' Much as in the Ifac Moscow conference, the largest single group of papers presented at the J.A.C. Conference was, in some direct or indirect way, related to the concept of adaptive control. Of course, the exact meaning of the term 'adaptive control' is still open to spirited debate. Some writers have used the terms 'optimalization', 'self-optimization', and 'identification' with the same connotation as adaptive control, while others have preferred to differentiate carefully between the various terms. For example, J. E. Gibson (*1*) has offered the following definition: 'An adaptive control system provides a means of continuously monitoring the system's performance in relation to a given figure of merit or optimum condition and a means of automatically modifying the system's parameters, by a closed-loop action, to approach this optimum'. Gibson considers an optimalizing control as a sub-class of adaptive control. Another viewpoint, advanced by P. Eykhoff and O. J. M. Smith in their conference paper (*2*) and a specially prepared discussion, proposed the following terminology:

> '*Identification:* the derivation of knowledge about the dynamics and/or non-linearity of a system during normal operation.
>
> '*Optimalization:* the control of a system (plant) in such a way that the profit, yield, efficiency or some other *economic commodity* is maximum in spite of changes in the system or in the environment.
>
> '*Adaptation:* the control of a system in such a way that the *information processing* is optimum in spite of changes in the system or in the environment (e.g., changing spectrum of the input signals or load disturbances).'

In other words, Eykoff and Smith advocate that: under 'optimalization' we want to correct with respect to the *process function*, and under 'adaptation' we want to correct with respect to the *process dynamics*. (The program committee apparently preferred to separate optimal and adaptive control papers, although some overlap still existed.)

Utilizing multiplication plus integration as the simplest type of 'learning', Eykhoff and Smith proposed an optimalizing system with process-dynamics identification. This is a self-optimum-seeking system capable of accepting a sinusoidal or a random test signal. Interestingly enough, if disturbances already exist in the input, then the addition of a test signal may not be necessary at all.

A particularly interesting paper by K. C. Smith (*3*), discussed the application of sinusoidal techniques to a class of very simple adaptive control systems, commonly termed single-parameter-regulating or automatic-gain-control systems. The discussion was limited to the special class of systems in which adjustment of

*If you are a regular reader of *Control* you will probably feel that the Ifac Congress was adequately reviewed in the July, August and September issues of the magazine. Yet we do not think that we are flogging the subject unduly in now publishing news reports on the two post mortems that have recently been held. In fact, we think you may be interested to compare them. The American one appears on page 128 and the British on page 132.—EDITOR.

†'Overboard with the frequency response', *Control*, Aug. 1960, p. 87 ff.—EDITOR.

forward loop gain alone is sufficient to ensure an almost invariant response to command inputs, in spite of large changes in environmental conditions.

The adaptive system discussed is shown in Fig. 1. A sine-wave test signal is added continuously to the basic loop input and to a model. An adaptive computer compares the responses of the model and basic loop and then adjusts the controller by some method based on this comparison. With a sinusoidal test signal two types of measurement can be made, either the amplitude or phase shift of the basic loop output at the test signal frequency. Fig 2 shows the two possible types of adaptive computer for making these measurements. Several cases are analysed in the paper to show how the adaptive loop responds to changes in the process gain factor.

In a discussion following the paper, R. L. Cosgriff commented that the systems to which these simple adaptive schemes apply are important and very real. Cosgriff further stated that, although these systems were not very versatile, they were by far the simplest and least expensive of all the adaptive systems.

Among the other adaptive control papers, A. B. Bishop and H. R. Chope's (*4*) proposed an adaptive control system using a multiple regression technique for optimal control of a multivariate nonstationary process. The regression technique is a statistical tool for the determination of dynamic relationships among the controllable variables. Knowing the basic functional relationship between the controllable variables and the output variable allows calculation of the regression coefficients (using standard computer hardware). These coefficients, in turn, provide a statistical description of the current process performance upon which is based decisions concerning how to apportion the error among the controllable variables. Inherent in the system design is assurance of stable system operation regardless of the apportionment decided upon.

Many papers have been written which suggest feedback system designs for controlling variable or incompletely known processes, the ultimate objective being to design a system with a satisfactory transfer function that is insensitive to process variation. P. E. Fleischer (*5*) contends that this method of design yields poor results whenever a significant amount of instrument noise is present in the system. Fleischer outlines a method of design to attain both small sensitivity to process variation and insensitivity to instrument noise. The method, while being only approximate, is based on minimizing the expected value (with respect to the plant) of the mean square error.

E. B. Lee (*6*) presented a general method for designing optimum controllers for linear processes with one or more independent forcing functions. The analytical method is based on the principle of optimality, a new principle in the calculus of variations due to Bellman (*7*). Applications of the method were made to: (a) design of minimum-energy controllers, (b) design of minimum-response-time controllers, and (c) design of minimum-error controllers.

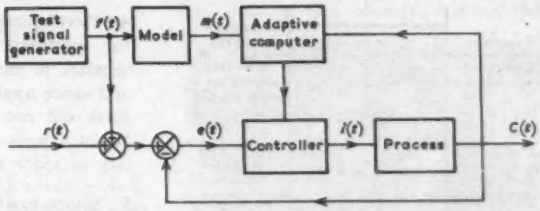


Fig 1 Application of an adaptive control loop

R. Bellman, of dynamic programming fame, co-authored a paper with R. Kalaba (*8*) concerned with the difficulties of studying control processes, having high-dimension state vectors, by way of the theory of dynamic programming. R. Kalaba (who actually presented the paper) discussed a technique for dealing with finite dimensional systems of large dimension with various methods of successive approximations and quasi-linearization. An interesting discussion followed the paper. S. S. L. Chang suggested that the technique discussed was unnecessarily sophisticated for studying the designated class of systems. To quote Dr Chang: 'It is like using a high-precision microscope to look at a person's head'. R. Kalaba rebutted this by giving examples of several more complicated systems covered by the technique. Still unable to convince Chang, Kalaba finally proposed the technique as 'just another mathematical tool', not particularly meant to compete with existing analytical methods.

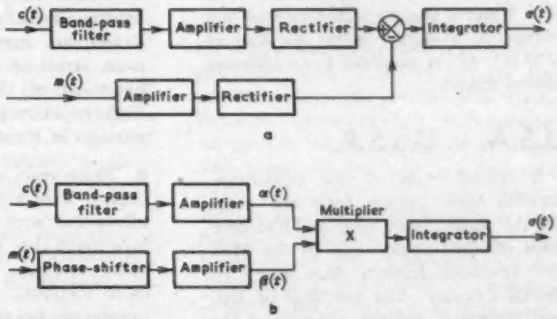


Fig. 2 Two types of adaptive computer **a** amplitude-measuring **b** phase-shift-measuring

After offering still another adaptive control terminology, G. W. Johnson and F. G. Kilmer (*9*) discussed the use of integral transforms for algebraic analysis and design of a class of linear-variable and adaptive control systems. The technique is said to be particularly applicable to the design of input-sensitive adaptive control systems.

New results in linear filtering and prediction theory were presented by R. E. Kalman and R. S. Bucy (*10*). The methods employed are claimed by the authors to represent major improvements and generalizations of the conventional Wiener filtering theory. The mathematical complexity of this paper was somewhat formidable for your correspondent (as well as for many others at the conference) so, for the present time at least, the digestion of this work will be left to those already well-grounded in this area of mathematical development.

Optimum control of chemical processes

The optimum control of a generalized chemical process plant was the subject of a group of three papers presented at one of the sessions. Alternative approaches were presented to the optimum control of a stirred-tank reactor postulated by T. J. Williams and R. E. Otto (*11*). The reactor (see Fig. 3) is believed to represent a typical chemical process, and the problems encountered in controlling it are thought to be typical of chemical process control in general. The optimum control of the chemical plant was considered from the point of view of varying the plant inputs in such a way as to maximize the average rate of return on the investment. W. Kipiniak (*12*) and A. E. Beecher (*13*), in papers both co-authored by L. Gould, propose similar methods of synthesis of the dynamic system (i.e., the reactor) using techniques of the calculus of variations. However, details of the differing methods and philosophies were difficult to ascertain from the oral discussion alone (one of the papers was unavailable in preprint form). Both papers outline a design procedure which leads to the formulation and evaluation of an optimum control law for the sys-

tem, leaving the designer complete freedom in the selection of a system configuration to realize this law. Both authors postulated the feasibility of using on-line computer control to accomplish the control scheme. The question of realizable and/or reasonable computer capacity to accomplish these schemes was left somewhat unsettled.

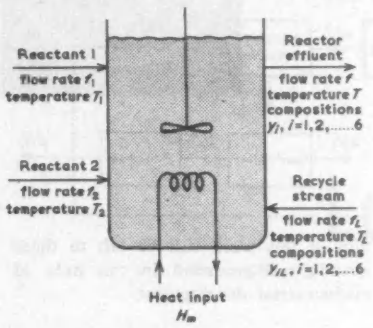


Fig. 3 Williams' plant—scheme of reactor section

In the third paper of the group, by R. E. Boydston (*14*) the emphasis was entirely on the development of computer control schemes to effect optimum control of the reactor. A slight modification of a dynamic control technique that was introduced in earlier works by Kalman *et al* (*15, 16*), is proposed as an optimum control scheme.

U.S.A. v. U.S.S.R.

A special event of the conference, drawing wide interest from the press, was the panel report by several Ifac delegates on their impressions of the Moscow congress. Reports were given by Harold Chestnut, first president of Ifac, who is control systems engineer at the General Electric Company, Schenectady, N.Y.; Prof. John G. Truxal of Brooklyn Polytechnic Institute*; N. B. Nichols, vice-president for engineering of Taylor Instrument Company; Joel O. Hougen of Monsanto Chemical Company; Prof. John E. Gibson of Purdue University; and John C. Lozier of Bell Telephone Laboratories. Approximately a hundred members of the United States delegation to Moscow attended the M.I.T. meeting. Informal reports were also made by Dr I. Flügge-Lotz of Stanford University, Nate Cohn, vice-president of Leeds and Northrup, and Dean Gordon Brown of M.I.T.

Highlights of the panel report included the following:

1 Automation research has top priority in the Soviet Union with complete Government sanction to proceed at full speed.

*A review of the Ifac Congress by Prof. Truxal appeared in *Control*, Aug. 1960, p. 85 ff.—EDITOR.

2 Soviet control specialists are currently producing about 50% of the world's literature on control theory and they avidly absorb all available reports on work being done by western nations.

3 Soviet specialists in control are more aware of our work then we are of theirs.

4 Development of control systems for industrial applications is totally separate in the U.S.S.R. from military and space applications. The U.S. delegates did not even see any sign of Soviet experts on computers for military or space applications.

5 Soviet machines, devices, and systems are beginning to show originality, whereas three years ago they were simply copies of western versions.

6 There seems to be a very big gap between the theoretical work of the research institutes and application to machines and processes in industry. Five new institutes, employing from 2000 to 10,000 workers each, are being started to help bridge this gap.

7 Soviet control engineers, while receiving a broadly based scientific foundation, are required to specialize on some aspect of control from the very beginning of their university career. Technical obsolescence is not yet a problem in Russia.

8 Three years ago, Soviet automation experts were not quite sure of themselves and were eager to demonstrate how much they knew—a sort of inferiority complex. This year they were more confident, with less eagerness to exaggerate or claim leadership. They are, however, very proud of their work and are highly motivated.

9 Nearly all of the papers were considered to be of good quality, although some of the Russian theoretical papers were described as offering 'eloquent solutions to non-existent situations'.

10 Although most of the discussion was of the U.S.S.R. *v.* U.S.A. type, all of the speakers made it a point to praise individual papers from many countries that were worthy of special note.

Other papers

Our future reports will be concerned with some of the remaining papers given at this conference. A copy of the final program and listing of papers and how to order them may be obtained from the A.S.M.E. Order Department, 29 West 39th Street, New York 18, N.Y., until 31 December 1960.

Next J.A.C. Conference

The next JAC Conference will be held June 28–30, 1961, in Boulder, Colorado. The Instrument Society of America will be the organizing sponsor, with A.S.M.E., A.I.E.E., I.R.E. and A.I.Ch.E. serving as co-sponsors. Professor H. M. Paynter, M.I.T., Cambridge 39, Mass., has agreed to serve as Program Chairman. Papers from all parts of the world will be accepted for review by the sponsoring societies for possible inclusion in next year's progam.

Your American Correspondents

J. LOWEN SHEARER, ROBERT S. SCHER, KARL N. REID, JR.
Massachusetts Institute of Technology

References

1. Gibson, J. E.: 'Making Sense Out of the Adaptive Principle'. *Control Engineering*, Vol. 7, No. 8, August 1960, p. 113.
2. Eykhoff, P., and Smith, O. J. M.: 'Optimalizing Control with Process-Dynamics Identification'. Paper No. 60AC-15 presented at J.A.C.C., Sept. 1960. To be published by I.R.E.
3. Smith, K. C.: 'Adaptive Control Through Sinusoidal Response'. Paper No. 60AC-14 presented at J.A.C.C., Sept. 1960. To be published by I.R.E.
4. Bishop, A. B., and Chope, H. R.: 'Regression Techniques in Multivariate Adaptive Control System'. Paper No. 60AC-11 presented at J.A.C.C., Sept. 1960. To be published by I.R.E.
5. Fleischer, P. R.: 'Optimum Design of Passive-Adaptive, Linear Feedback Systems with Varying Plants'. Paper No. 60AC-12 presented at J.A.C.C., Sept. 1960. To be published by I.R.E.
6. Lee, E. B.: 'Design of Optimum Multivariable Control Systems'. Paper No. 60JAC-5 presented at J.A.C.C., Sept. 1960. To be published by A.S.M.E.
7. Bellmann, R.: 'Dynamic Programming'. Princeton University Press, Princeton, New Jersey, 1957.
8. Bellman, R., and Kalaba, R.: 'Reduction of Dimensionality, Dynamic Programming, and Control Processes'. Paper No. 60JAC-6 presented at J.A.C.C., Sept. 1960. To be published by A.S.M.E.
9. Johnson, G. W., and Kilmer, F. G.: 'Integral Transforms for Algebraic Analysis and Design of a Class of Linear-Variable and Adaptive Control Systems'. Paper No. 60AC-10 presented at J.A.C.C., Sept. 1960. To be published by I.R.E.
10. Kalman, R. E., and Bucy, R. S.: 'New Results in Linear Filtering and Prediction Theory'. Paper No. 60JAC-12 presented at J.A.C.C., Sept. 1960. To be published by A.S.M.E.
11. Williams, T. J., and Otto, R. E.: 'A Generalized Chemical Processing Model for the Investigation of Computer Control of Chemical Processes'. A.I.E.E. Paper No. CP60-119 presented at Winter General Meeting, Feb. 1960, New York.
12. Kipiniak, W., and Gould, L. A.: 'Dynamic Optimization and Control of a Stirred Tank Chemical Reactor'. Paper No. TP-60-982 presented at J.A.C.C., Sept. 1960. To be published by A.I.E.E.
13. Beecher, A. E., and Gould, L. A.: 'Considerations in the Design of a Dynamic Control System for Generalized Chemical Processing Model Considered as a Nonlinear System'. Paper CP-60-980 presented at J.A.C.C., Sept. 1960. To be published by A.I.E.E.
14. Boydston, R. E.: 'Dynamic Solution to a Generalized Chemical Processing Model'. Paper No. CP-60-979 presented at J.A.C.C., Sept. 1960. To be published by A.I.E.E.
15. Kalman, R. E., Lapidus, L., and Shapiro, E.: 'On the Optimal Control of Chemical and Petroleum Processes'. Report RC-76, I.B.M. Research Laboratory, Yorktown Heights, New York.
16. Kalman, R. E., and Koepcke, R. W.: 'The Role of Digital Computers in the Dynamic Optimization of Chemical Reactors'. Report RC-77, I.B.M. Research Laboratory, Yorktown Heights, New York.

PEOPLE IN CONTROL

by Staffman

I greatly enjoyed **Arthur Porter's** Ultra jubilee lecture, *The evolution of instruments*, at the Festival Hall, London, last

PORTER
jubilating

month. Professor Porter, who is a pioneer of systems engineering and Dean of Saskatchewan University, roamed happily through nearly the whole range of topics interesting to the control engineer. Apparently there is 'terrific collaboration' with the medical fraternity at Saskatchewan, the engineer being treated as a high priest of the operating theatre. Full marks to Ultra, incidentally, for celebrating their 25th anniversary in this manner.

E.M.I. Electronics have been taking a very great interest in North America of late, and now I learn that their Managing Director, **Clifford Metcalfe,** is there at the moment on a three-week tour. He is visiting the Halifax, Nova Scotia, factory of E.M.I.-Cossor Electronics—he is President of that company—and will tour Fairbanks-Morse plants in the U.S.A. and meet E.M.I.'s other U.S. agents. E.M.I.'s **R. H. Booth** has also left for North America, although in his case it is for a two-year tour of liaison duty.

In the same strain, E.M.I.'s American associates, Fairbanks-Morse have formed an International Division with Italian-born **Pier F. Talenti** as Vice-President, and **Frank Gervasi** as Vice-President for European operations, with headquarters in Rome.

A new company, Southern Analytical Ltd., has been formed to handle the analytical and instrument activities of Southern Instruments. Members of the new company's Board include **W. B. Horner** (General Manager), **H. M. Davis** (Chief Engineer), and **J. A. Colls.** The Chairman is **Phillip Sellars,** Southern Instruments' Vice-Chairman.

The monocyclist in my illustration is the Manager of Sperry Gyroscope's Bracknell Division, **H. B. Sedgfield,** who

SEDGFIELD
precessing

is, in fact, demonstrating gyroscopic precession at Sperry Bracknell's open day—see page 132. He tells me that they have now got over their Blue Streak set-back and that he is very optimistic for the Division's future prospects. Incidentally, I gather that Sperry's Managing Director, **R. Broadbent** proposes that a similar exhibition should be held by the Brentford Division.

Bill Vincent, Sales Manager of the (U.S.) Fisher Governor's Gas Division has been in this country, and on the

VINCENT CARPENTER
gassing

Continent, for some weeks, discussing his company's work in the high-pressure gas distribution field. Apparently the advent of high-pressure gas production, and the extension of high-pressure natural-gas mains, means that national and, indeed international, gas grids are on the way, and Vincent has been demonstrating that adequate high-pressure gas-regulation equipment is available now. In my picture he is explaining an h.p. gas regulator to gas-engineer **P. T. Carpenter** at the Rochester factory of Elliott-subsidiary Fisher Governor Co.

Incidentally, **J. R. Moore,** Fisher Governor's Rochester Manager, has been appointed Assistant General Manager of all the Elliott valve companies which, in addition to Fisher Governor, include James Gordon Valves, Farris Engineering and Black Automatic Controls.

Texas Instruments of Bedford are now going in for 'vertical' rather than the more usual 'horizontal' organization, the idea being to make one department completely responsible for a range of products from development, through manufacture, to dispatch. They feel that this will shorten the chain of command and so improve service to customers. This reorganization has entailed the appointment of **W. A. Yates** as Marketing Manager, his previous position as Field Sales Manager being taken over by **A. J. Barnes.** Dr **J. T. Kendall,** who was Marketing Manager, takes charge of the Transistor Department which now

includes all transistor people including development and manufacturing personnel; Dr **J. A. Powell** will head the Diode and Rectifier Department in similar fashion. The Quality Assurance Manager **J. M. Waddel,** however, will be quite independent and responsible only to the Managing Director, **Dudley Saward.**

F. S. Barton, who was appointed to the Board of Mullard Equipment on September 1, is a man of some calibre. Since 1955 he has been Counsellor, Defence Research and Supply, in the U.K. High Commission in Ottawa. Previously he was Director-General of Electronic Research and Development in the Ministry of Supply, and during the war was Director of Radio Engineering in the British Air Commission, U.S.A.

Since hearing of Barton's appointment to Mullard Equipment's Board, I was intrigued to learn that he had also been appointed to the Board of Painton & Co., the electronic component people of Northampton. However, I gather that there is little or no connexion between the two events.

I hear that **Frederick Baillie,** who joined Cambridge Instrument as Production Manager in August, is responsible for all aspects of production planning at the company's three factories—Cambridge, Muswell Hill and North Finchley.

AUTHORS IN CONTROL

Donald Lidgley (co-author with D. C. Lowe and D. A. Mackintosh—below—of *Controlling the manufacture of laminated plastics,* page 88) graduated in natural sciences from Selwyn College, Cambridge in 1950 and served in the Education Branch of the R.A.F. until 1952. He was a process chemist with the Northern Dairies Group for a year, and joined the Research and Development Department of Thomas de la Rue's Plastics Division in 1953. There he was responsible for various developments connected with copper-clad materials, the outdoor use of decorative Formica, and glass-based industrial materials. In 1959 he joined de la Rue's Technical Department to form a development group, becoming Technical Manager in October 1959.

MACKINTOSH

LOWE

Dennis C. Lowe was an assistant chemist with Maclean's from 1942–44, and served in the Army from 1944–48. The next four years were spent at the Royal College of Science, Imperial College, where he received his A.R.C.S., D.I.C., and Ph.D. in physical chemistry, the latter being for research into the structure of molten slags under the sponsorship of the British Iron and Steel Research Association. He joined Thomas de la Rue in 1952 as a works chemist in the security printing company. In 1953 he transferred to the Plastics Division (now Formica Ltd) as Assistant Technical Manager, becoming Technical Manager in 1955 and Research Manager in 1957. Dr. Lowe was appointed to the Board of Formica Ltd in 1959.

Donald A. Mackintosh studied brewing until joining the Technical Department of Formica Ltd in 1949 as a Technical Assistant. From 1951 he was engaged in process applications engineering with particular emphasis on high-pressure hot-water process heating and instrumentation. He joined the Formica Engineering Department as Process Engineer in 1959. Mackintosh is particularly interested in cybernetics.

Michael James (*Farnborough impressions,* page 94) joined de Havilland Propellers in 1951 to undertake research and development work on the early marks of guidance, fusing and aircraft systems for the Firestreak guided missile. In 1956 he joined the Blue Streak team and was responsible for the guidance, power, and safety systems for this ballistic missile. He is at present responsible for the electronic and system engineering in de Havilland's new group working on automation. James holds a Diploma of Electronics (Honours) from Southampton University, is a Member of the Brit.I.R.E. and sits on their Technical Committee, a Member of the S.I.T. and serves on their Control Committee, and is also a Member of the Instrument Society of America.

E. H. Werninck (*Stockholm shows the world,* page 97) received his technical education at Northampton Polytechnic, and, shortly after entering industry,

JAMES

WERNINCK

specialized in the design of fractional horse-power motors. While with Plessey he came into contact with special applications in actuation, potentiometric recording and other motor-driven control devices. In 1952 he joined Evershed and Vignoles as designer specializing in servo and instrument motors. For the past three years Werninck has been Evershed's Chief Applications Engineer. His work involves the study of servo systems in general and position and speed-control systems in particular.

A. M. Andrew (*Information theory—the fourth London Symposium,* page 100). See page 126, September 1960.

J. J. Foody (*Controlling v.t.o.l. aircraft at transition speeds—2,* page 105). See page 125, September 1960.

T. H. Gossling (*Programming a digital computer for process control,* page 109) graduated in mathematics from Queens' College, Cambridge, in 1958. Since then

GOSSLING

he has been working with Ferranti Ltd at their Wythenshawe (Manchester) laboratories. After a short period spent in the study of guided weapons systems, he has been engaged on the development of general programming techniques for the Argus digital process-control computer, and on specific applications to industrial processes.

J. H. Bowen (*Automatic control of power reactor systems—B,* page 114). See page 126, September 1960.

J. Lowen Shearer, Robert S. Scher and **Karl N. Reid** (co-authors of *Look at America,* page 126). see page 126, September 1960.

NEWS ROUND-UP

from the world of control

—— NUCLEAR ENERGY ——

A visit to Winfrith

The U.K.A.E.A.'s Atomic Energy Establishment at Winfrith, Dorset, is responsible for research into the physics and engineering technology of reactor systems, and is also the headquarters of the international Dragon project. The latter involves the design, construction and operation of a 20-MW high-temperature gas-cooled experimental reactor. A hasty tour of the Winfrith establishment, recently, impressed *Control* greatly, although there was so much to see—exotically-named reactors like Dragon, Zenith, Nestor, Hector, Nero, Helen and Zebra, and 'exponential stacks' and assemblies like Bicep and Scorpios 1 and 2, either operational or under construction or modification—that it was practically impossible to sort the control engineering wheat from the nuclear chaff. However, the whole technology is, of course, based upon the massive use of automatic controls.

An engineer observes flux changes during the removal of fuel elements from the Zenith reactor

Winfrith's work on analytical design for reactor control systems, typically employs the root locus method to establish the type of controller required and to indicate the value of the more important parameters. A medium-sized analogue computer is used initially, a Pace being used for the more rigorous analysis. Work is also proceeding on reactor safety circuits incorporating magnetic core and semiconductor switching, such solid-state working being inherently reliable and having high switching speeds.

Among the many instruments of control interest in use at Winfrith, is a transfer function analyser which modulates the reactivity of a reactor sinusoidally and measures the amplitude and phase of the resulting neutron flux oscillation over a range of modulation frequencies. Data obtained in this manner indicate the inherent stability characteristics of the reactor and help assess the performance of the control loop.

Another interesting development is a magnetic flowmeter for insulating liquids such as transformer oil. Basically this operates by applying a 50-c/s field across the flow, so polarizing the molecules of the liquid to give a millivoltage signal. The amplitude of this signal is dependent upon the rate of flow.

Though it found Winfrith quite fascinating, *Control* was disappointed that it was not possible to spend more time on individual devices.

—— BUSINESS ——

E.E.-G.E.C. merger?

The news that English Electric and General Electric are discussing the possibility of a merger has come as a great surprise and, although the financial press are trying hard to suggest that they expected something of the sort, we suspect that the City too was surprised. Admittedly, the financial wizards did appear to think that E.M.I. was about to take over G.E.C., and this does suggest that they knew something was going on, but as, in fact, E.M.I. settled for Ardente—hearing aids and electronic components—instead, they were at least several orders of magnitude out in their prognostications.

Little beyond the bare fact that E.E. and G.E.C. are discussing a merger is apparent from their joint statement, which merely says: 'The Boards of the English Electric Co. Ltd and the General Electric Co. Ltd, have been jointly considering the general position of the British electrical industry. They feel that many activities of their two groups are complementary and having regard to the interests of shareholders and employees have agreed to explore immediately the practicability of a merger of the two groups by means of a holding company. Time is required to examine details and to formulate any definite proposal to shareholders, but a further statement will be made as soon as possible'.

However, from hindsight, it does seem quite reasonable that these two large electrical concerns should merge, if only to enable them to present a united front to A.E.I. English Electric has assets of around £89m and employs 84,000 people, and G.E.C. £87m and 70,000 employees, so their combined strength would cap that of A.E.I. whose assets total about £166m. Furthermore, G.E.C. is said to have suffered from the lack of a firm management policy, and whatever English Electric may lack, it is not strong management. Another advantage, lies in the possibility of a joint research endeavour. Both companies expend very large sums on research into similar problems. This follows from their interest in similar products, although E.E. does have a rather larger stake in

heavy engineering than G.E.C., the latter being stronger in the domestic market.

It is interesting to speculate on the effects a merger would have on individual concerns within a joint E.E.-G.E.C. Group, and, for that matter, on users of their equipment. The first change would presumably occur in the world of nuclear energy. At the moment there are three large nuclear consortia, each consortium being connected with one of the three electrical giants. An E.E.-G.E.C. merger would, presumably, reduce the number of consortia to two.

Then there is the electronic valve industry. How would G.E.C.'s M.O. Valve be integrated with English Electric Valve? In fact, this should not be too difficult as E.E.'s subsidiary Marconi's Wireless Telegraph held a half-share in M.O. Valve at one time, and English Electric Valve stemmed from the Marconi valve laboratories at Chelmsford. At the moment, both E.E.'s Marconi Instruments and G.E.C.'s Watson make X-ray equipment; would they continue to compete or would one retire from this very difficult market? These are merely examples of the problems which would arise.

On the other hand, the giant engineering group must surely be a more efficient unit than the smaller organization which tends to dissipate its energies in vain attempts to 'keep up with the Jones's'. The two companies have a great deal in common, and a merger between them is surely no more strange than de Havilland's disappearance into the maw of Hawker Siddeley. Incidentally, English Electric is a 40% holder in the British Aircraft Corporation (Vickers 40%, Bristol 20%) through English Electric Aviation. Is it possible that the apparent success of the aircraft industry's mergers has had an effect on thinking in the electrical world? The aircraft mergers were to a great extent due to the high cost of research in that industry. The aircraft industry spent a £100m on research in 1958, more than any other industry, but the next highest expenditure, £64m, was for research into electrical engineering.

Sperry Bracknell on show

Of the several light industries in Bracknell, Sperry Gyroscope is one of the largest. In the past, Sperry in Bracknell were concerned mainly with defence projects, their commitments to the Blue Streak ballistic missile program being extremely heavy. When the Blue Streak debacle occurred, there was a great deal of local uneasiness about the labour situation. Indeed a member of another company in Bracknell grumbled to *Control* at the time that siting a secret defence plant in a new town was foolish because it forced up local wage-rates and, if the project was halted for political reasons, as happened with Blue Streak, the local labour market was flooded.

In the event, these gloomy prognostications were not fulfilled to any great extent: Sperry, Bracknell, turned their efforts towards industrial equipment, although still carrying out a certain amount of defence work, particularly on Sea Slug.

However, in order to let local people know that Sperry really was in Bracknell to stay, a one-day exhibition of the company's products, to which the general public was invited, was held in the erstwhile secret factory on September 24. To Sperry's surprise, over 5000 local people turned up, and appeared to show great interest in the firm and its products. Several visitors were so impressed that they applied for positions with the company on the spot and, even more surprising, a certain amount of solid commercial business was done.

The whole affair was so successful that Sperry's Brentford Division are to hold a similar exhibition.

COMPONENTS

Hughes in Scotland

Following closely on International Rectifier, who opened their new semiconductor factory at Oxted in May, yet another company of American origin —Hughes International (U.K.) Ltd.— has started manufacturing semiconductors in this country. Unlike International Rectifier (G.B.) Ltd., who are 50% controlled by the Metal Industries Group, the Hughes concern has no association with any British organization.

UNVEILED Checking belts of Hughes semiconductors for use in automatic assembly lines. Hughes International (U.K.) have recently unveiled a semiconductor factory in Glenrothes, Fife

Hughes International have erected a new and rigorously air-conditioned factory at Glenrothes, Fife, where production began in August. The location was deliberately chosen because of the availability of suitable labour, its geographical remoteness being little handicap as transportation costs are negligible with products of this size.

It is anticipated that sales will be mainly to makers of computers and data-handling equipment. Initial production will be concentrated on semiconductor diodes. The first stages in the assembly of these diodes are carried out on automatic rotary machines; subsequent operations are mostly of a semi-automatic nature. In addition to semiconductors, which are expected to be the main product of the factory, ferrite memory matrices for computers are being assembled at Glenrothes. These are built up from American components for re-export to the U.S. —this procedure apparently being economically justifiable.

B.C.A.C.

Autocontrol symposium

The Symposium on Automatic Control held late last month under the sponsorship of the British Conference on Automation and Computation, was arranged by The Institution of Mechanical Engineers. The Symposium was based on the British contribution to the First International Congress of the International Federation of Automatic Control—see *Control*, July (p. 84) August (p.84), and September (p. 92). (The corresponding U.S. post mortem is reported in *Look at America*, this month.) The two-day Symposium was arranged in nine separate parts: Session 1, Linear and sampling systems; Session 2, Linear, non-linear and optimal systems; Session 3, Statistical theory and theory of switching; Session 4, Self-adaptive systems and mathematical methods; Session 5, Technical visits and education; Session 6, Speed and position control; Session 7, Industrial applications (steelworks and engineering); Session 8, Industrial applications (processes); Session 9, Telecommunications, information processing and analogue computing.

Dr J. H. Westcott, *Control*'s systems consultant, reports Session 5 on the facing page.

Control in Russia

Mr J. Knox, in introducing Session 5 (Technical visits and education) with a general survey, gave it as his sombre opinion that although what we had seen was not particularly impressive, the implication for the future of what we had seen should give us pause lest we be overtaken by default.

Mr G. M. E. Williams took up the thread from the point of view of education. Here one saw an impressive—even heroic—attempt to educate the masses for technology. Mr Williams drew an analogy between German industry before the war and Soviet education. In Germany, restricted by the Versailles treaty, one saw significant storage of design and research effort whose accumulated effect was released into effective production the moment the treaty was set aside. In his opinion this educational phenomenon in Russia was working the same way. The storage bath was quickly filling up. How long, he ominously demanded to know, before the plug is pulled out? We all felt a trifle dampened by this foreboding.

Mr D. Barlow continued with a very thoughtful summing up of the situation as he saw it. The Soviet system operates like a pulsed system—the mean level is very low, but the peaks are so high as to be out of all proportion by western standards. To bring matters home, he suggested we imagine ourselves in our present situations but under the Soviet system. Tomorrow the Prime Minister announces that 50 per cent of all distillation columns will be computer-controlled by 1965, by which time the newly-formed Institute of Control will be employing 5000 chartered engineers. While we were still under the influence of this shock to our systems, he went on to confess that he could not suggest where the Soviet system was bound, for in their plans no allowance is made for the fact of human nature—nevertheless he was sure it was going somewhere, and in a very businesslike fashion.

The audience was much relieved after all this bogey-bogey talk to hear Mr W. S. Elliott demanding to know what all the fuss was about. What did the speakers feel the Soviet system could achieve that our commercial system could not? Before lapsing back into our comfortable customary complacency, some of us had had a twinge of doubt! Well, tomorrow we must get organized! J. H. WESTCOTT

Institute of Control?

'I learned more about the Moscow Ifac Congress at the London Symposium, than I did in Moscow' those were Professor Pestel's words at the dinner given by the Institution of Mechanical Engineers in honour of the British authors on September 28. Mr J. F. Coales, leader of the British delegation to Moscow and Chairman of the B.C.A.C. Symposium, extended a special welcome to distinguished foreign guests. Although the symposium was the first sponsored by B.C.A.C. and had been planned as a 'domestic' affair, it had nevertheless attracted several control experts from overseas and their contributions to the proceedings had been most valuable.

Professor Richards (Southampton University) spoke on the need to give careful thought to the future of automatic control in this country. He advocated the formation of an Institute of Control to provide a corporate activity for all those interested in the subject. Professor Macmillan (University College, Swansea) suggested that an Institute of Control (or similar title) should be State-sponsored and have aid and research facilities with close collaboration with universities and research organizations. Dr Rosenbrock (C.J.B.) observed that many different branches of engineering, mechanical, electrical, chemical, aeronautical and so on, had control problems which were similarly of interest to each other; mathematicians, physicists and engineers could all benefit by an exchange of views. This had been achieved at the B.C.A.C. Symposium, and he doubted whether a separate institute was necessary. Mr. G. M. E. Williams (Northampton C.A.T.) endorsed this view.

Other speakers followed, and three points of view emerged: a separate institute; a B.C.A.C. consisting of three groups each with many member-societies; a new form of B.C.A.C.

It is possible that this discussion may result in something definite being arranged this month.

DATA PROCESSING

Memory development

During a recent visit to Plessey's research establishment at Roke Manor, *Control* saw some of the development work going on there in the field of high-speed computer memory stores. Besides work on magnetic films and low-temperature solid-state devices, which are likely to form the basis of stores in the not-too-distant future, Plessey are considering means of speeding up stores based on the established square-loop ferrite cores.

A number of their ferrite-core stores are at present being evaluated at Manchester University for possible use in the ultra-high-speed Ferranti Atlas computer. The fastest of these systems is unconventional in using two cores, of 0·05 in. o.d., per binary digit of storage. Even with such small cores it is apparently necessary to restrict the amount of flux switched in them, to avoid overheating and an excessive demand for power from the drive transistors.

Another development is a new ferrite, which switches under coincident current operation in less than 0·4 μsec.

Final assembly of matrix cores at Plessey's Towcester Works

This has made possible storage systems with access-cycle times less than 2 μsec and capacities up to 4096 words. Plessey are attempting to develop standard circuits for storage systems which can be assembled to meet customers' individual requirements. This is being done both for the very-high-speed stores referred to above, and for somewhat slower and larger-capacity systems of up to 16,384 words, with access-cycle times around 6 μsec.

MACHINES

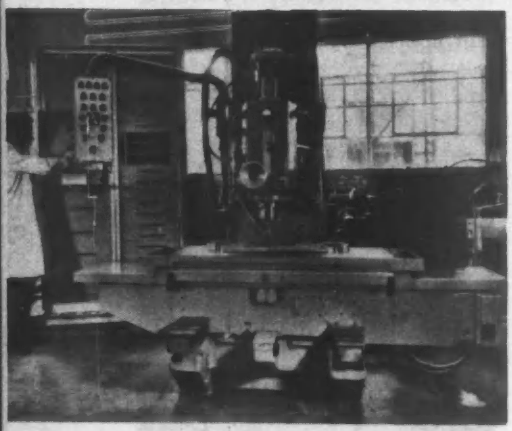
Anticipatory miller

A new German milling machine, the Droop and Rein FS80 vertical mill, has been fitted with the E.M.I. Electronics Emicon tape-control system, which now incorporates a device for anticipating errors and stopping the machine before they are made. Normally, tape-controlled machines have a safety system which operates to halt the machine immediately an error has occurred. The new system incorporates an 'angle safety unit' which foresees any program error or irregularity in the tape, and brings the safety circuits into operation before the cutter arrives at the error point. Once the irregularity has been investigated and, if necessary, corrected, cutting can continue.

E.M.I. claim a large saving to be possible with the new system, for they point to the example of a workpiece with a complicated profile which has

an irregularity near the end of the program.

The Emicon system on the Droop and Rein mill gives contour control in any two axes and fine step control in the third dimension. Zero shift in all axes facilitates accurate positioning of the workpiece. It is further



Droop and Rein vertical mill fitted with E.M.I. Emicon control which includes an angle safety unit to anticipate possible machining errors—U.K. agents, Elgar Machine Tool Co.

claimed that the Emicon system enables the input program to be corrected for the actual size of the cutter in use, even after re-grinding during the course of machining operations.

PROCESS CONTROL

Quality control symposium

Gas chromatography

A private symposium on quality control which Elliott-Automation sponsored recently, aroused a considerable amount of interest, a large hall within Caxton Hall being filled to capacity. It will be recalled that Elliott's are to manufacture various equipments developed by the (American) Consolidated Electrodynamics Corporation, and the first paper, which was on process control with continuous analysers, was by Dr. D. J. Fraade of the Analytical and Control Instrument Division of that company. He described closed-loop process control based upon vapour phase chromatography, in a natural-gas processing plant of the Reef Corporation at Big Springs, Texas. This employs a process chromatograph and a pneumatic control system for their fractionating train. The analyser samples the bottom product of a de-ethanizer for ethane as an impurity, the object being to control the ethane content of the propane product, and thus increase its value from 0·39 cents/gal as a gas, to 4·0 cents/gal as propane product. It was estimated that on this basis the cost of installing the controlling chromatograph would be covered in six months, and this estimate has in fact been substantiated. In another example, a chromatograph controls steam to the reboiler of a de-propanizer column. Phillips Petroleum computed the costs of such an installation at a butane-isobutane recovery unit and found that the instrument paid for itself: (a) every two weeks as a consequence of increased product recovery; (b) every six weeks by improved product quality; (c) in seven months by reduced consumption of services such as steam and pumping power.

In the question period which followed Dr Fraade's paper, there was some discussion of the problems of long lags in controlled plant versus high-speed chromatography. One questioner was unhappy about the validity of the sample analysed by the chromatograph, but was assured that it was a true sample. Another wondered about the actual number of process chromatographs really required, and Dr Fraade replied that his company laid down an initial order for ten, then tripled this and recently increased it to 60—all this in under a year. He estimated that 40–45% of their output was for closed-loop control. Dr Fraade was extremely unhappy about collaboration with user industry: 'Once our equipment goes through the user's main gate, we never see it again'. An interesting side issue raised, concerned a computer-controlled 'micro plant' for Esso. Apparently there is a growing need for fully-automated miniature pilot plants, complete with stream analysers and computers, for research purposes.

Optimat for Coryton

The Optimat process control computer was discussed in a paper by J. Barnes of E-A Automation Systems. This works on the basis of a trial and error 'game', and is said to take 1/10 or 1/20 of the time that a man would need to arrive at an improved position. A full-scale trial of Optimat is to be carried out at Mobiloil, Coryton. It will control a distillation column, analysis being by a process chromatograph; the object is to obtain the maximum product output while preserving product quality to the agreed specification.

After Mr Barnes' paper, the question of lags in the controlled plant was raised once again, the discussion becoming quite warm. How can a machine operating on a trial and error basis control a process which may take many hours to settle down? However, Mr Barnes appeared confident that this was possible, and the rest of us will have to await the results of the Coryton trial.

Kybernetes control

During a recent visit to Hagan Controls, *Control* saw something of the Kybernetes data-handling system, which is said to perform logging, scanning, computing, programming and optimizing operations. Basically the system is designed to monitor signals from a multiplicity of measuring points around a plant. Information from the point of measurement is taken in the form of an electrical analogue signal and converted into numerical form for display or recording.

The system operates with: a mean analogue-to-digital conversion time of 11 msec; an input capacity of up to 1000 points; a scan rate of 4 points/sec; an overall accuracy of 0·1 per cent or 1 digit; any type of output device. Although Kybernetes is basically an on-line monitor, when fitted with a computing unit it will provide optimizing control of a process.

Hagan Controls was formed in September 1959 as the result of an agreement between Plessey and Hagan Chemicals and Controls Inc., of Pittsburgh, U.S.A.

Honeywell control

An integrated computer control system, which incorporates all instrumentation from primary elements to final controls, is to control a complex power network of Philadelphia Electric Co. Introduced by Minneapolis-Honeywell Regulator, the system is based on the Honeywell 290 digital computer, a general-purpose solid-state device designed for process applications. The design incorporates high-speed internal operation, magnetic-core and auxiliary magnetic-drum memory, random access of input and output channels, and a special instruction vocabulary.

IN BRIEF

Elliott-Bendix-Ericsson affairs. Bendix Corp. (U.S.A.) has disposed of its holding in Elliott-Automation, this having been reduced from some 33% to 7% as Elliott's expanded. Co-operation between the two will continue, and C. C. Tillinghast, a Bendix Vice-President remains on Elliott's Board.

Bendix Ericsson U.K. Ltd has been formed by Ericsson Telephones and the Bendix Corp. to manufacture and market instruments and electronic devices. Ericsson's Instrument Division has been acquired by Bendix Ericsson which will have Dr J. H. Mitchell, Ericsson's Research Director, as Managing Director.

The AMPEX CP-100 is a compact, extended-frequency instrumentation tape recorder/reproducer. Tape transport, motor drive amplifier, heads, power converter, controls and all-transistorized plug-in record/reproduce electronics are contained in a single 13¼" x 19" x 33¼" mobile case. The CP-100 operates on 28-volt DC, with 48 to 400 cycle converters available for other power sources. Data is recorded by direct or FM carrier techniques on up to 14 analogue tracks. The CP-100 offers frequency response to 200 Kc at 60 ips or expanded recording time of 24 minutes for 100 Kc data at 30 ips on a standard 10½" reel. Transport tape speeds – 1⅞, 3¾, 7½, 15, 30 and 60 ips – and plug in frequency determining units and equalizers associated with tape speeds, may be quickly changed. The versatile and mobile CP-100 performs reliably over a temperature range of from −50° F to +160° F, up to an altitude of 10,000 feet, in relative humidities to 95%... and is designed to withstand shocks and vibrations encountered in rugged mobile testing applications. This recorder may also be rack mounted if desired. For complete details write Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

Pick-off

by 'UNCONTROLLED'

TOWARDS THE END of last month I went down to Cardiff for the British Association's Annual Meeting, a gathering for which I have always had a sneaking admiration, although it is always difficult to sort the wheat from the chaff. This year there was little to interest the control engineer, unfortunately.

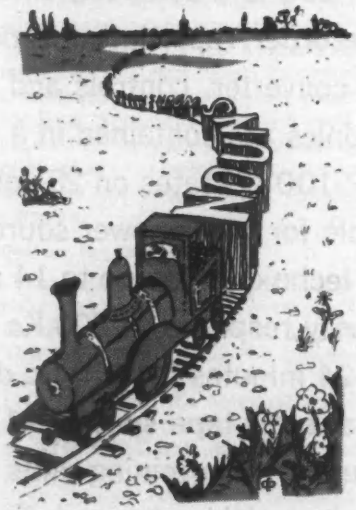
A continuous program of scientific films was shown. I saw films on the paintings of schizophrenic patients, the breakdown of a worker on a Canadian car-assembly line (why do the Canadians produce such good documentaries?), automation (very dull), and Einstein's theory of relativity. The latter (*circa* 1923) was good even if it did sometimes provoke sniggers from the scientifically sophisticated B.A. audience.

I ENJOYED THE S.B.A.C. show at Farnborough, although there was little new to be seen. The static exhibition was thought-provoking ('where is all the new equipment?') and the flying display nearly as thrilling as last year's—which was better than the previous year's, and so on. Apart from the R.A.F. displays, which are now so professional and near-perfect that the spectator misses the spice of vicarious danger, the flying was a little tedious. However, the Short S.C.1 vertical take-off aircraft quite stole the show. This is as impressive as anything I can recall in recent years. One wonders how any other way of doing it could ever have been contemplated, let alone brought to fruition. Sounding a cynical note: I heard one spectator suggest that an exhibition of historical aircraft would have been fun, to which his friend replied 'Surely they're *all* historical aircraft'.

WELL BEFORE the Farnborough show, one of my colleagues went ahead in the usual way and requested information from a number of intending exhibitors. Naturally he stressed our interest in control and instrumentation. Most of the early replies came from companies making paint, surface coatings, hose, and so on. While many of *Control*'s engineering friends sent material by return of post, it was noticeable that press-relations departments in many engineering firms are less efficient than their counterparts in companies producing 'semi-consumer' goods. I wonder why?

While on the subject of press relations, I may as well bring up another point. I have noticed that, since the easing of dollar restrictions, more and more of the press releases received in these offices have been concerned with imports from the U.S.A. It is good to see them, of course, but I am depressed by the thought that similar British equipment is constantly being introduced without corresponding publicity. That kind of modesty doesn't pay in business.

A FRIEND OF MINE was some time ago given the task of editing a tender for plant worth millions of pounds. He has lately let me see the notes which he prepared for his small team of assistants. I liked particularly his remarks about two kinds of bad writing that I have also found distressing myself. He wrote: 'One source of obscurity in the present



tender is the disproportion between the authors' vocabularies of nouns and verbs respectively. It is odd that technologists, who are concerned with doing rather than contemplating, should be so shy of verbs. Knowledge seems in some cases to be restricted to such verbs as 'operate', 'perform', 'carry out', and 'act'. Thus, equipment is not tested, but tests are carried out upon it. Structures do not support, they act as supporting members; or they perform the function of supporting. A more dangerous kind of obscurity arises from the use of long trains of nouns, most of them serving as adjectives'. Those 'long trains of nouns' can make time-saving shorthand for initiates, but they can be very confusing to outsiders or newcomers. A phrase like 'input output adder subtractor unit', which I saw in a report recently, might make even an expert stop and think for a millisecond or so.

LACKING THE FANTASTIC facilities of the daily press, we can still sometimes put up quite a fair show as far as speed is concerned. The Farnborough preview in last month's *Control* forced us to bring the issue out a few days earlier than usual so as to anticipate the show. A lot of hard work was put in by editorial, production and printing staff, and they managed to get the copies off to subscribers and distributors on 2 September.

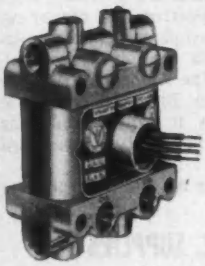
In that same issue there were some wry comments by the Editor on the popular press and its failure to notice the Ifac Congress last June. The *Daily Telegraph* came swiftly to the rescue, and on 6 September it began publishing a short series of articles on the 'Soviet Challenge in Automation', with a star billing for the Ifac Congress. *Control's* first article reporting the Congress appeared in July.

OWING TO sheer pressure on space, the review of the Ifac Congress in recent issues of *Control* had to be savagely cut. Quite an interesting article could be built from the axed paragraphs! I have rescued one of these from the unpublished part of Dr Westcott's ms. for his article last month. Referring to his visit to the Kiev Institute of Automation, Dr Westcott wrote: 'We were surprised to note a mechanical contrivance mounted on top of a cabinet which was in the nature of an advertising display. This device was turning the pages of a catalogue of instruments manufactured by the Institute, or to Institute designs, and each description was in Russian on one page and in English on the other. When asked about this our hosts said that they hoped to export their instruments. We later had even more convincing evidence of their seriousness in this direction when they gave each of us a package of commercial handouts—again in Russian on one page and in English on the facing page. As yet the instruments are of a simple and obvious kind, but in five years time, who knows?'

Circle No 85 on reply card for further details

Complete Control

is yours through . . .



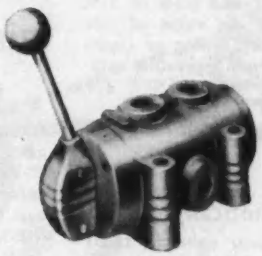
Skinner Solenoid Valves

There is a SKINNER VALVE for almost any flow application with a wide variety of media; air, oil, water, inert gases, hydraulic fluids, kerosene and petroleum

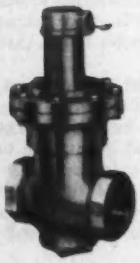
Four-way V9 series, a compact direct-acting all-purposes 4-way valve.

Rivett Hydraulic and Pneumatic Equipment

Includes valves and cylinders for pneumatic or hydraulic applications over an extensive range of types and sizes.



Lever-operated 4-way valve for manually operated directional control.



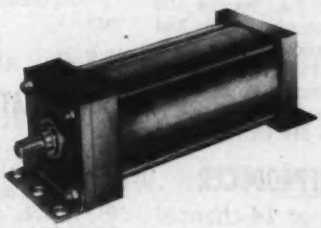
Atkomatic Solenoid Valves

Are available in sizes ¼"—3" in 2-way and ½"—4" in 3-way. Primarily for air, water, oil and steam applications.

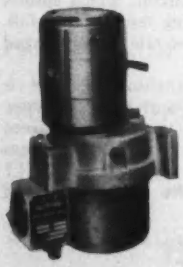
Type F 2-way pilot-operated valve.

Allen Air Hydraulic and Pneumatic Equipment

Covers a wide field of valves and cylinders for all applications. Also included is a range of air operated rotary indexing tables.



10" diameter pneumatic cylinder.



Oil-dyne

Complete packaged hydraulic power units, comprising motorised pump, reservoir and valve gear. Pressures range to 3000 p.s.i. with a displacement of 2 g.p.m.

½ h.p. pump and reservoir unit.

This range of equipment, the most comprehensive in the world, is available through British Arca Regulators Limited, together with their own established range of control equipment.

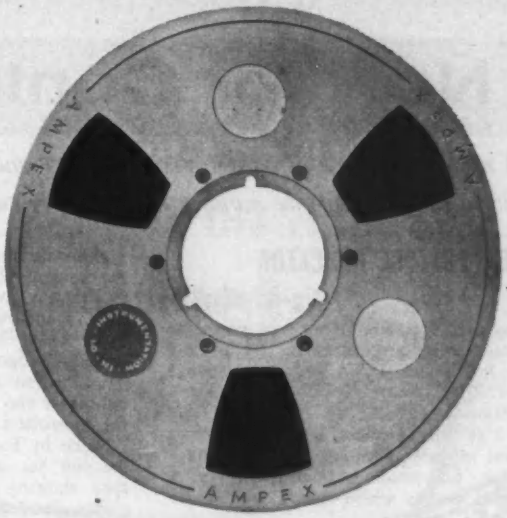
BRITISH ARCA REGULATORS LIMITED

SISSON ROAD . GLOUCESTER . ENGLAND

Tel.: GLOUCESTER 24901 Grams: Arcaregul, Gloucester

London Office: 25 Victoria St., London, S.W.1 Tel.: ABBey 4121

Circle No 86 on reply card for further details



AMPEX Instrumentation Tapes are premium quality magnetic tapes designed for analogue recording by any of the basic techniques. Magnetic properties include high sensitivity, and a wide dynamic range with a stable output throughout the life of the tapes. Exceptionally smooth, hard surfaces provide cleaner operation with less oxide shed, offering greater reliability and reduced maintenance. These tapes are available in configurations for a wide variety of applications. They are offered on acetate or Mylar* backing films, in thicknesses of 0.6, 1.0 and 1.5 mils, and in various widths and lengths. All are supplied on high-performance Ampex Precision Reels or on NAB-type reels. For application information write to Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

*DUPONT TM

New for Control

A monthly review of system components and instruments: for further information on any item, circle the appropriate number on the reply card facing page 182.

TEMPERATURE INDICATOR

digital display

Designed for measurement of jet-engine temperature, an instrument by B. and H. Instrument (U.S.A.) covers the range 0–1200°C. Accuracy between 500 and 1000°C is claimed to be ± 1°C, and ± 2°C outside these limits. A pointer gives coarse indication over the entire range, fine readings being made on a digital display which shows temperature in 0·5°C steps.

The Autotemp is marketed in Great Britain by Bryans Aeroquipment. A more detailed account of its operation appears in this month's *Ideas Applied* section (p. 119).

Circle **No 514** on reply card

OBLIQUE VALVE

counters concussion

An air-operated valve for controlling water, steam, and other media, at pressures up to 100 lb/in², is made by

Operates up to 100 lb/in²

Charles Winn. Sizes available are ¼–1¼ in. in bronze, and 2 in. in cast iron.

The valve opens at an air pressure of 40 lb/in², and closes by spring action. The anti-concussive effect is obtained from a damper consisting of a piston operating in a cylinder. On closure, a depression is created in the cylinder, so retarding the piston. The controlled medium enters the cylinder through orifices, the sizes of which determine the rate at which the cylinder is filled, hence the speed at which the piston is released.

Circle **No 515** on reply card

FLOW TRANSMITTER

pneumatic output

An area-meter transmitter measures rate of flow of various liquids at a maximum service pressure of 600 lb/in². Minimum and maximum rates of flow are 0–520 lb/h and 0–42,750 lb/h respectively, and accuracy is given as ± 2% of maximum flow. Standard signal-outputs are 3–27, 3–15, and 5–25 lb/in², the output being directly proportional to rate of flow. Transmission may be up to 1000 ft to indicators and recorders, or up to 400 ft for controllers.

Made by Bailey Meters and Controls, the unit has an indicating scale of 3 in. span showing percentage value of rate of flow and percentage value of transmitted signal. Maximum operating temperature should not exceed 350°F for sustained periods.

Circle **No 516** on reply card

AIRCRAFT RELAY

hermetically sealed

Four silver change-over contacts, rated at 15 A, 30 V d.c., or 200 V, 400 c/s, are provided on Hendrey's D.4750 relay. The contacts are sealed in a compartment separate from the energizing coil, which has a resistance of 260 Ω, continuously rated at 30 V d.c. Pull-in and drop-out voltages are respectively not greater than 18 V and not less than 2 V.

Ambient temperature range is − 60 to + 100°C, and maximum usable altitude is 60,000 ft; life expectancy is 2×10^4 at 15 A, and 1×10^6 at 5 A. Weight and dimensions are respectively 0·78 lb and $3 \times 3 \times 2\frac{1}{4}$ in.; this relay is also available for operation in 115-V, 400-c/s circuits. It is fully operational at an acceleration level of 15 *g*.

Circle **No 517** on reply card

DATA RECORDER/REPRODUCER

7- or 14-channel

A feature of this compact magnetic-tape unit is that it may be used in aircraft at altitudes up to 10,000 ft. Frequency response is from d.c. to 200 kc/s with a 25-dB signal-to-noise ratio. The unit will take either ½- or 1-in. tape on 10½-in. reels; six tape-speeds are provided, from 1½ to 60 in/s. Direct or f.m. carrier recording may be employed, and cumulative flutter is less than 0·6% peak-to-peak at 60 in/s. The Ampex CP-100 may be operated from 28 V d.c., or 115 V a.c., 60 or 400 c/s. It may be used in its carrying case, or mounted on a standard 19-in. rack.

For high-altitudes

Circle **No 518** on reply card

STABILIZED D.C. SUPPLIES

low ripple

A range of chokeless power-supply units includes four models; their output voltages are respectively ± 150, ± 200, ± 250, and ± 300 V, maximum output-current being 100 mA in each case. Voltage stability is given as better than 0·06%, and residual ripple as less than 2 mV, free from spikes. Effective source resistance is below 0·1 Ω, and output impedance at all frequencies is less than 2 Ω.

Made by Fraser, Speller Transformers, the unit uses paper capacitors only, and two unstabilized heater supplies (6·3-V, 3-A) are provided in addition to the main output. Mains input is 200–250 V a.c., selected in 10-V steps, and full stabilization is maintained for up to ± 10% random variation in mains voltage.

Circle **No 519** on reply card

SCINTILLATION MONITOR

accurate, compact

Three meter ranges are provided on the NE 148A, covering 0–0·03, 0–0·3, and 0–3·0 mr/h. A feature of this unit, which is made by General Radiological, is an auxiliary overload-circuit, which ensures that the meter reading remains over full-scale should the dose-rate greatly exceed full-scale value.

The unit is transistorized, and is powered by self-contained batteries. Weight is 4 lb, and the unit is designed to withstand rough usage and rigorous climatic conditions.

Circle **No 520** on reply card

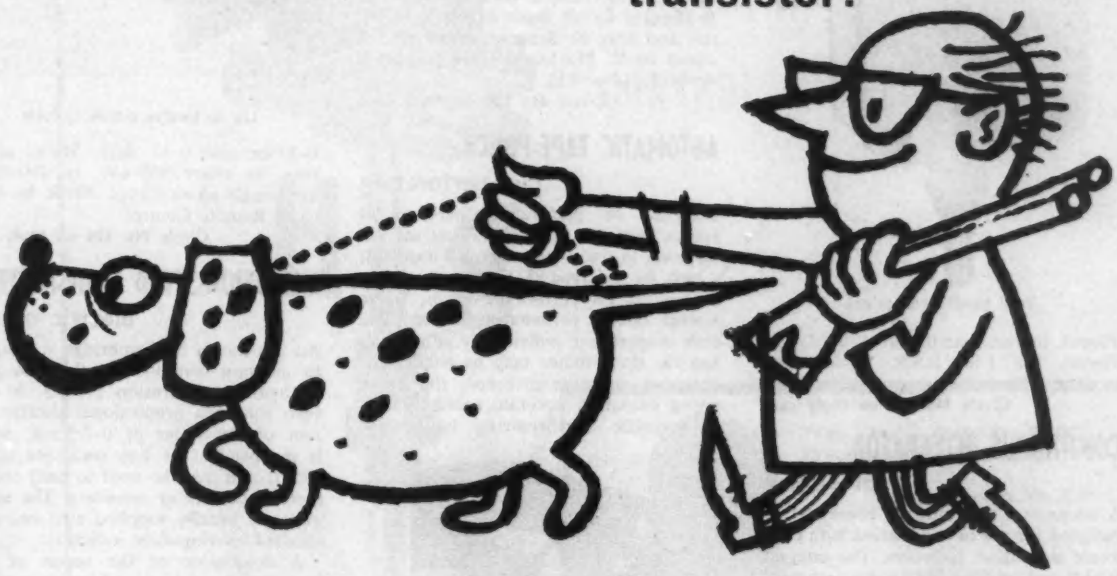
FLOW CONTROLLER

for water or gases

Designed for control of gas flow between 0·1 and 50 ft³/h, or water flow between 1·0 and 20 gal/h, this controller needs an available operating pressure (supply pressure minus back pressure) of 2–3 lb/in².

The body is normally made from brass, but for use with corrosive liquids a stainless steel body is available. The

Hunting for the right transistor?



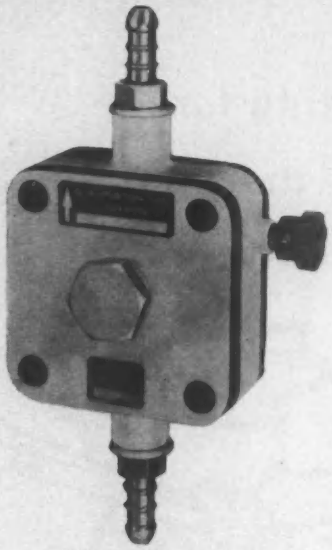
You can waste a lot of time covering the whole field, following false scents and even barking up wrong trees when all the time the transistor you want is already there in the Ediswan Mazda range specially developed for industrial applications. Let us know, on your letterheading the applications you have in mind and we will send you full information about suitable Ediswan Mazda transistors.

These could help

The latest developments in our industrial range include the XA161 and XA162 for high speed switching applications. These are germanium pnp diffused alloy mesa transistors with a minimum gain/bandwidth product of 25 Mc/s and 35 Mc/s respectively. Features include **low saturation resistance, low total stored charge, and high collector dissipation.**

EDISWAN
MAZDA
SEMICONDUCTORS

Associated Electrical Industries Limited
Radio & Electronic Components Division
Semiconductor Department, 155 Charing Cross Road, London W.C.2
Tel: GERrard 8660 Telegrams: Sieswan Wescent London
CRC 15/75



Will handle corrosives

Flostat minor, manufactured by G. A. Platon, has ¼-in. B.S.P. female connexions.

Circle **No 521** on reply card

CONTINUOUS INTEGRATOR

digital display

A continuous integrator by Honeywell is designed for use in conjunction with electronic strip-chart recorders. The integral is obtained by counting known areas enclosed by the curve, the total being presented as a permanent record on the left side of the chart and simultaneously on a four-digit counter.

Accuracy is within 0·5% of full-scale area for integration between 5 and 100% full scale. The action of this instrument was described in *Ideas Applied* for September.

Circle **No 522** on reply card

HYDRAULIC OSCILLATOR

automatic reciprocation

This device is a double-acting cylinder available in a range of strokes from ¼ to 2 in. in ¼-in. steps. Reciprocation is obtained by a built-in pilot-operated directional valve which supplies oil at pressure to each side of the piston alternately. Stroke speed may be varied from 6 to 60 strokes/min. Maximum working pressure is 1000 lb/in², and for a 2-in. stroke at 60 strokes/min maximum flow requirement is 1¼ gal/min.

Made by Hydraulic Machinery Drives, who recommend as the operating fluid a high-grade hydraulic oil of viscosity 90-120 Redwood seconds (at 45°C).

Circle **No 523** on reply card

LIQUID-LEVEL CONTROLLER

pneumatic output

A controller designed to maintain a required level in open or enclosed containers will operate in the latter at pressures up to 900 lb/in². A displacer, made from a material suitable for the liquid in question, is suspended partially submerged in the liquid. Variations in level alter the displacer's apparent weight proportionally, and the changes in apparent weight are compared with a force applied by a set-point spring. The difference between them is used to determine the output in the range 3–15 lb/in². Proportional-band adjustment is provided in order to assist stability.

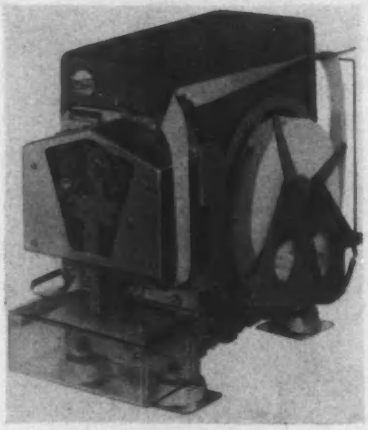
Made by their German associates, the controller is available from British Arca. It requires an air input of up to 40 lb/in², and may be flange-mounted on the vessel itself. Maximum level change is normally 14 or 8 in.

Circle **No 524** on reply card

AUTOMATIC TAPE-PUNCH

fast perforating

Designed to perforate paper-tape at speeds up to 110 characters/sec in response to multi-wire electrical impulses, a unit by Teletype (U.S.A.) is available in versions for perforating 5-, 6-, 7-, or 8-level binary permutation codes. The code magnets are individually adjustable, and the drive motor may be either synchronous or series-governed, the latter giving extremely accurate speed-control. A magnetic synchronizing mechanism



Magnetic synchronizing system

provides a pulse to trigger the signal circuits at the optimum operating point in each cycle.

Available from Westrex, the B.R.P.E. 110 tape-punch may be supplied with double tape-attachments, and multiple units for ganged operation.

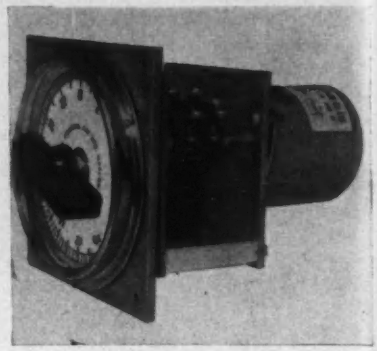
Circle **No 525** on reply card

SYNCHRONOUS TIMER

hand-setting

A synchronous timer utilizing continuously-variable timing-cams is fitted as standard with one or two change-over microswitches, but up to twelve timed circuits and twelve change-over switches may be fitted. The timer is preset by hand to the desired time-interval, and returns to zero over the timing period.

Switching capacity is 6 A at 230 V a.c., and time ranges are available between



Up to twelve timed circuits

0–30 sec and 0–12 days. Mains supply may be either 400–440, or 200–250 V a.c., single-phase 50 c/s. Made by Electrical Remote Control.

Circle **No 526** on reply card

EXTRUSION-SPEED TRANSMITTERS

electric output

An instrument by Cambridge is designed to measure continuously the ram-speed of hydraulic extrusion presses. It converts this to a proportional electric current of the order of 0–7·5 mA, which is independent of line resistance up to 2000 Ω and may be used to feed one or more indicators or recorders. The transmitter is usually supplied with one illuminated moving-scale indicator.

A description of the action of this instrument may be found in this month's *Ideas Applied*, p. 117

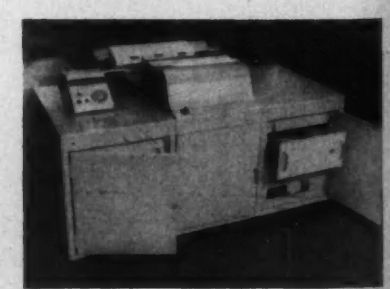
Circle **No 527** on reply card

AUTOMATIC SCANNER

digital logging

This unit is basically a digital self-balancing potentiometer which scans a number of analogue inputs and converts them to digital form. It can then print on a log-sheet the voltage level of each point scanned. Alarm contacts may be fitted for high or low limits, and the machine arranged to print inputs outside these limits in red. Various alternative arrangements are possible, one of particular interest being that in which the unit scans continuously, operating the alarms whenever necessary, but printing-out the scanned voltages at regular but less frequent intervals; voltages outside limits will be printed as they occur. A break-in

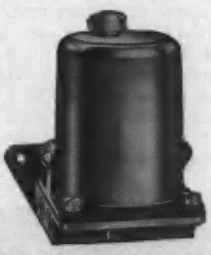
Wide variety of sequence



TRANSMISSION

CONTROL

"On plant" mercury-in-steel air-operated proportional temperature controller.
Publication No. R39



"On line" air-operated receiving controller. *Publication No. R31*

Mercury-in-steel air-operated temperature transmitter
with Polyester resin glass-fibre cover, stainless steel base, stem and bulb. *Publication No. T39.*

High thermal response. Wide range of temperatures.
Standard output air pressure, 3-15 p.s.i. Small and compact.

NEGRETTI & ZAMBRA

The name that means precision all over the world

NEGRETTI & ZAMBRA LIMITED
122 Regent Street, London W.1

facility may also be provided so that one particular channel is indicated continuously on a tube display.

The Bailey Meter's Digilog is normally designed for 0–10 mV d.c. signals such as those from thermocouples, but it will also accept suitable digital inputs. The scanning switches are divided into ten-channel units which may be used in cascade to accept a virtually unlimited number of inputs. Scanning speed for analogue inputs (checking upper and lower limits) is 5 points/sec, print speed being 1 point/sec. Scanning and printing times are approximately halved for digital inputs. The 30-in. print-carriage can give a horizontal distribution of readings, for use where a temperature gradient across a series of positions is to be observed (e.g. in reactors).

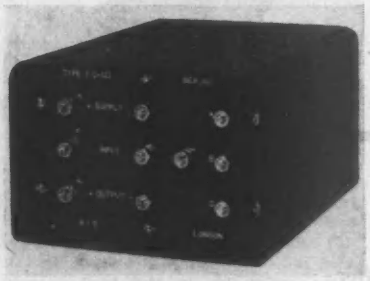
Circle **No 528** on reply card

LINEAR CONVERTER

d.c. output oc frequency

A 'frequency to d.c.' converter covers a range of 5–10,000 c/s, providing a d.c. output directly proportional to the frequency or pulse-rate of the input. Three frequency tappings are provided, covering 5–500, 5–3000, and 5–10,000 c/s. The output, for maximum frequency of tapping used, is 10 mA ± 1% into loads between 1 Ω and 1000 Ω, or 10 V ± 1% into a 1000-Ω load. A 1-mA output is obtained from each tapping at 10% of the maximum frequency for that range. The input voltage may be from 50 mV–10 V p-p, input impedance being 100 k Ω.

The FC-121 is made by Grunther Industrial Developments; it is transistorized and requires a 12-V d.c. supply, consuming about 80 mA. The FC-122, a capacitance tachometer system is also available; this is basically the FC-121 fitted with an oscillator for working a



Wide frequency-range

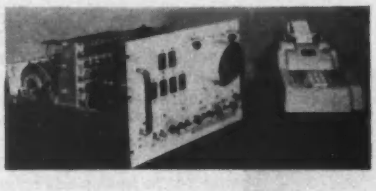
CTD-023 capacitance transducer. It will measure angular speeds from 300 to 180,000 rev/min using a single reference on the rotating shaft. Lower speeds may be measured by using multiple references, such as are provided by a toothed wheel.

Circle **No 529** on reply card

DATA MONITORING SYSTEM

digital display

A data-monitoring and display system for use on industrial plant provides a tabulated numerical record of slowly varying quantities. It measures, displays,



Digital and c.r.t. display

and records voltages derived from transducers distributed about the plant. The unit also has a 5½-in. cathode-ray tube, on which voltages varying on a convenient time-scale may be displayed; its timebase has seven sweep-speeds from 5 sweeps/sec to 20 sweeps/sec.

Range of voltage measurement, accurate to within ± 0·1%, is 0–109·9 V, positive or negative. Input selection may be effected manually by a rotary switch, or automatically by an electromechanical rotary selector. Automatic input-selection allows all 48 inputs to be scanned in about two minutes, and as each source voltage is read, an identifying code number is automatically indicated on the control panel and printed out. Made by Redifon.

Circle **No 530** on reply card

TRACE SHIFTER

for oscilloscopes

This instrument enables up to ten signals in sequence to be displayed on an oscilloscope by vertically displacing each signal relative to its predecessor. Its main use is with transient-storage oscilloscopes where it facilitates study of cycle-by-cycle variations or a series of transients.

The Cawkell TS1 provides either five or ten steps, minimum interval between each being 30 μsec. Step amplitudes (positive going) are 0·5–1·0 V for five steps, or 0·25–0·5 V for ten steps. Change in shift-voltage is initiated by a square-wave gate-signal derived from the oscilloscope, gate-input required being about 50 V. The unit is powered by a self-contained 9-V battery, and uses transistors throughout.

Circle **No 531** on reply card

GALVANOMETER AMPLIFIER

very low drift

This direct-coupled transistor amplifier is suitable for the amplification of signals down to zero frequency, where a very low drift is required. Frequency response is within 0·2 dB down from d.c. to 2 kc/s, 0·5 dB to 3 kc/s, and is less than 3 dB down at 6 kc/s. The maximum voltage gain is 1000 into a 50-Ω load, and the drift under these conditions is 20μ V/°C at input or 0·5 mA/°C at output.

Maximum input, balanced or unbalanced, is ±120 V d.c.; output is push-pull (not about earth), and the maximum is ±35 mA into 50Ω. Output impedance is 65Ω. The TGA 2, made by Armstrong Whitworth, has a temperature stabilizing system, controlled by a three-position switch which allows the system to be turned off when not required. A 'warm-up' position gives rapid heating to bring the unit up to normal working temperature, when it may be set to normal stabilization.

Circle **No 532** on reply card

QUICK LOOKS

Meters. Panel-mounting meters by Taylor Electrical use centre-pole movements with sensitivities from 5 μA d.c. Four models cover nominal scale lengths from 1¼ to 4½ in., the scales being designed to eliminate shadow.

Circle **No 533** on reply card

Connectors. A range of aluminium connectors by Plessey will operate safely within the temperature range − 55 to + 155°C. Designated Mark 5, they have minimum voltage ratings of 250 V a.c.; current ratings up to 60 A are available, with maximum contact resistance of 0·002 Ω.

Circle **No 534** on reply card

Power supply. A stabilized d.c. supply has outputs of + 300 and − 300 V d.c., each capable of 0–100 mA output current. A heater supply gives 6·3 V at 5 A, unstabilized. Made by Feedback, the SD-97 has a stabilization factor [(change in V a.c. input)/(change in V d.c. output)] of greater than 300. Mains input may be from 105–250 V a.c., 45–65 c/s.

Circle **No 535** on reply card

Linear displacement transducers made by Pye operate on the differential inductor principle. Nominal ranges are 1, 2, 4, 6, and 8 in. Excitation frequency is normally 3 kc/s, but operation is possible at 50 kc/s. Excitation voltage should be between 5 and 20 V.

Circle **No 536** on reply card

Stroboscopic tachometer. The 1531-A, made by General Radio (U.S.A.), produces white-light flashes of 1 to 6 μsec duration over a fundamental speed-range of 110 to 25,000 rev/min. The three ranges are 110–690, 670–4170, and 4000–25,000 rev/min, and accuracy is quoted as ± 1% of dial reading after calibration on the middle range. The U.K. representative for this device is Claude Lyons.

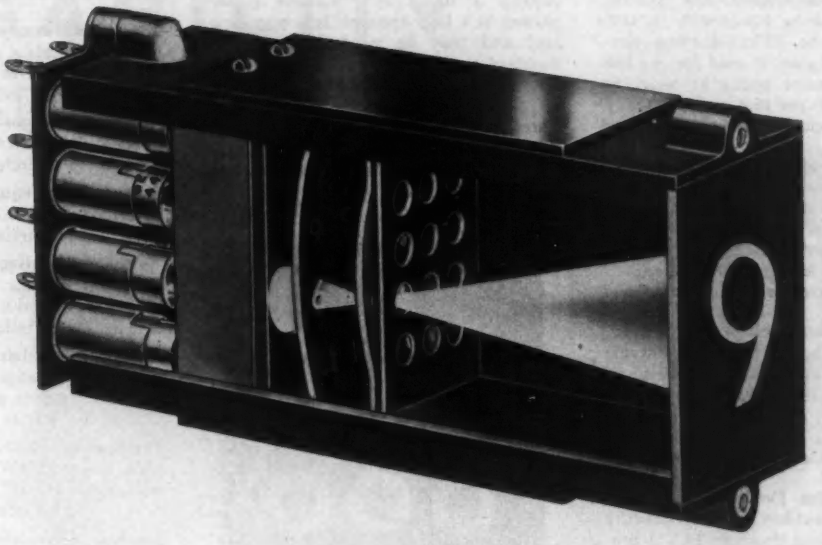
Circle **No 537** on reply card

Miniature magnetic drums, designed for airborne use, can hold 100,000 bits of information. Developed by I.B.M., the stainless-steel drums weigh 6 oz., and measure 3 in. both in length and diameter. It is claimed that they will withstand stresses of more than 15 *g*.

Circle **No 538** on reply card

Printing counters. Single or double units are available from Stonebridge Electrical. The former are normally six-digit totalizing counters using electrical impulsing. Double units are normally fitted with two totalizing units, or one totalizing unit plus one unit giving date and time information. Maximum impulsing rate is

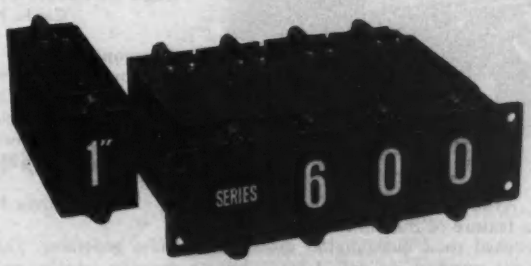
In-line Digital Display



Think of a number

—from 1 to 12, or any combination of letters, symbols or fractions, in white or colour, projected in clear, bold characters on to a screen for one plane presentation—and you will see the tremendous application of this C.I. Digital Display Unit. A system of 12 lamps which can be remotely controlled, projects through a system of lenses the figure, letter or symbol of your choice on to a viewing screen. Moreover, any number of these units may be grouped together or panel mounted with a common screen. Alignment is assured with perfect eye-appeal and a very wide angle of viewing.

Type numbers	*600 (for 6·3 volts).*
Operating Voltage	*6·3 volts, standard; also available 12 or 24 volts.*
Power Consumption	*2 watts.*
Figures	*Illuminated. 1" high by ⅝" wide.*
Case	*Matt black plastic with 2 fixing holes.*
Weight	*10 ounces.*



Single or grouped units

Counting Instruments Ltd · Elstree Way · Boreham Wood · Hertfordshire · England

Telephone: ELStree 1382

ten per second, and printing and resetting are carried out in 100 msec and 500 msec respectively.

Circle **No 539** on reply card

High-speed check-weigher. The Automa mechanical-handling equipment, in conjunction with the Elliott/Automa electronic check-weigher, is used for the fast handling of biscuit packs at weighing speeds up to 120 per min.

Circle **No 540** on reply card

Vacuum couplings. A complete set of rapid-action couplings is announced by Appleby and Ireland. Claimed to guarantee leak-tightness better than 10^{-9} atm. cm³/sec, the joint is closed by a single movement of a lever-controlled cam.

Circle **No 541** on reply card

Torque gauges made by Waters (U.S.A.) are marketed in the U.K. by International Engineering Concessionaires. Ranges are available from 0·005–0·6 to 2–40 oz in., with chucks up to ¼-in. diameter capacity.

Circle **No 542** on reply card

Welding controller. Designed for control of small spot-welders, the Lancashire Dynamo Electronic Products FCT.3 provides synchronous timing from ½ to 5½ cycles in ½-cycle steps, with a full range of stepless heat-control. It is suitable for welding machines up to 15 kVA on 440-V supplies, dependent upon duty-cycle.

Circle **No 543** on reply card

Digital voltmeter. The Electro-Logic (U.S.A.) Model V-1 is claimed to have an accuracy better than 0·5% on standard d.c. ranges of 0–2·5, 0–25, and 0–

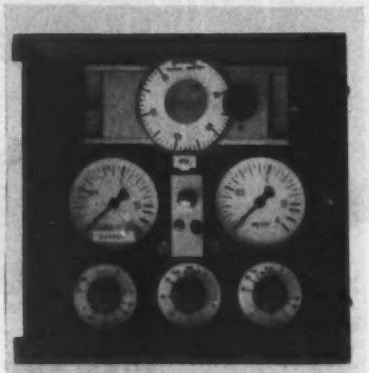
250 V. Available from Scientific Furnishings, a feature of this unit is that it may be switched to a quasi-digital mode in which the numbers do not 'frame', but slide smoothly past the windows.

Circle **No 544** on reply card

Electronic Announcer. This instrument will replay a number of messages up to a combined duration of about 16 minutes, and is for use where announcements have to be repeated at intervals. It consists of a rotary recording-drum, easily removable to permit a change of text, a set of push-button switches, and an amplifier capable of operating a number of earphones or a loud-speaker. It is transistorized and may be operated from any standard a.c. supply.

Circle **No 545** on reply card

Three-term controller. Designed as a receiver controller for use with pneumatic transmitters having ouputs in the range



3–15 lb/in², the series 52 is available from British Arca. The control mechanism employs a force-balance system, and a pneumatic adjustment of the desired value may be provided if required.

Circle **No 546** on reply card

Flight recorder. The latest Midas recorder, by Royston Instruments, is the cassette-loading CMM 400/7C. It has six continuous and independent signal channels, and a single time-code channel. Time multiplexing on the signal channels allows for logging of up to 270 flight parameters. Recording capacity is eight hours.

Circle **No 547** on reply card

Spectrophotometer. The SP200 infra-red spectrophotometer, made by Unicam Instruments, is an inexpensive double-beam instrument designed for routine analysis. The complete range of the instrument (15·4 μ — 2 μ) is covered in a single ten-minute scan.

Circle **No 548** on reply card

Telescopic stacker. A lifting-truck and telescopic stacker by Bishop (Birmingham) Engineering, is claimed to have a smaller turning-circle for a given length of fork than any other. It has a 5-ft lift, and is supplied with lift capacities of 8, 10 or 15 cwt.

Circle **No 549** on reply card

Pulse generator. The Solartron GO 1005 provides single or double rectangular pulses of 100-V amplitude. Repetition rate may be varied from 10 c/s to 1 Mc/s, and controls are provided to vary pulse-width and signal-delay. Triggering may be external or internal.

Circle **No 550** on reply card

INDUSTRIAL PUBLICATIONS

25th Anniversary of Ultra Electric (Holdings) Ltd, is celebrated in a descriptive booklet, '*Ultra* 25'.

Circle **No 554** on reply card

Automatic weight-control is the subject of data sheet AW4 from Elcontrol.

Circle **No 555** on reply card

Stud welding equipment by Philips is described in their recent leaflet RCL 5909. Circle **No 556** on reply card

Automatic lighting control. Publication E 1631-01 shows Lancashire Dynamo Electronic Products' improved ALC.3 system. Circle **No 557** on reply card

Totally-encapsulated capacitors for use over a wide range of ambient temperatures are listed in a leaflet from Waycom.

Circle **No 558** on reply card

Tachometer. Racal's transistorized analogue unit (SA.507) is described in their publication 185 D 1.

Circle **No 559** on repy card

Synchro accessories and mounting instructions for Muirhead servo-components are shown in a recent 8-page pamphlet. Circle **No 560** on reply card

Precious-metal thermocouples are described in a pamphlet from the Baker Platinum Division of Engelhard Industries. Circle **No 561** on reply card

'Transport Electronics News' is the title of a booklet to be issued every two months by the Advisory Panel on Electronic Computing and Control Devices of the British Transport Commission.

Circle **No 562** on reply card

Centrifugal pumps. The Alcon Thames range, in sizes from 1 to 5 in., is the subject of a leaflet from Arthur Lyon.

Circle **No 563** on reply card

'Research at Sunbury' tells of the various projects and activities at the B.P. Research Centre.

Circle **No 564** on reply card

Instruments by Venner Electronics are listed in their 16-page catalogue.

Circle **No 565** on reply card

All-attitude inertial platform. A miniature unit by the Norden Division of United Aircraft Corporation (U.S.A.) is illustrated in their 20-page booklet.

Circle **No 566** on reply card

Analogue computer. A leaflet from Elliott Brothers describes the Panellit G-Pac Mk. 2 centrally-patched computer.

Circle **No 567** on reply card

Contributions to the aircraft industry by Ferranti are illustrated in their recent booklet AE.5.

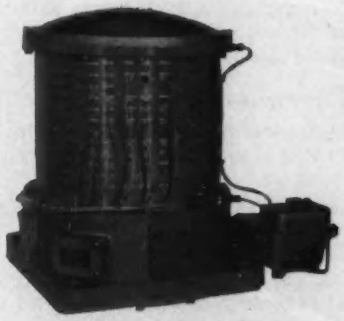
Circle **No 568** on reply card

Corrosion. The treatment of industrial effluents is described in a leaflet from Acalor. Circle **No 569** on reply card

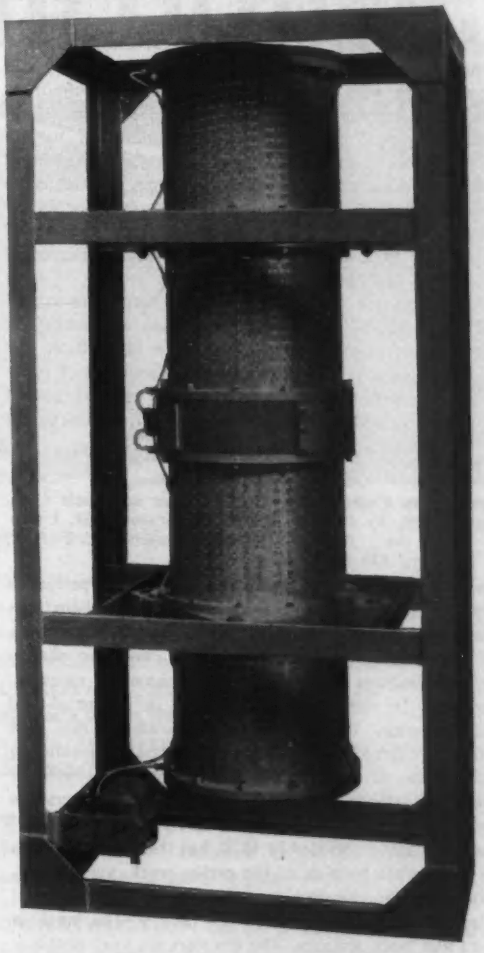
Magnetic compass pilot. Sperry's unit for automatic follow-up steering of small ocean-going vessels is shown in Publication 921. Circle **No 570** on reply card

MEGABILITY

versus Binary Digititis*



1 megabit to 4 megabits



Magnetic storage drums afford the most economical method of medium-access storage of information.

The new range of Sperry type C Magnetic Storage Drums provides to computer designers and users a flexible range of storage capacity with a "building-block" growth potential, directly related to the increasing demands on the complete system.

SPERRY

Magnetic Storage Drums

SPERRY GYROSCOPE COMPANY LIMITED
INDUSTRIAL DIVISION
Great West Road, Brentford, Middlesex.
Telephone: ISLeworth 1241. Telex: 23800

Book Reviews

Impulses

Impulse-Voltage Testing *by* **W. G. Hawley.** *Chapman & Hall. 1959. 183 pp. £1 12s.*

Impulse strength is now one of the most important design criteria for high-voltage equipment of power systems. This volume in the well-known series of monographs on electrical engineering dealing with the impulse-voltage testing is, therefore, a very timely publication.

The book starts with general considerations and definitions. Then the basic impulse circuits are discussed in terms of the Heaviside operational calculus. The description of various types of impulse generators follows, and the methods of measurement and recording of impulse voltages are treated in detail. Finally the testing procedures are described for dielectric materials, line insulators, transformers, lines, cables and capacitors. The appendices include some useful numerical values and practical data.

The book is written by a specialist with very wide experience and it is exemplary in its thoroughness and clarity. It gives an excellent theoretical introduction to the subject and discusses all practical problems involved. It should be of interest and value to anyone engaged on this type of work in universities or in industry.

T. TCHORZEWSKI

C.R.O.s

Encyclopaedia on Cathode-Ray Oscilloscopes and their Uses, 2nd Edition 1959, *by* **John F. Rider** *and* **Seymour D. Uslan.** *John F. Rider Inc., New York, and Chapman and Hall, London. 1337 pp. £10 10s.*

The cathode-ray oscilloscope dates from the same period as the beginnings of the commercial development of radio telegraphy, but since its early development it has been constantly improved and it has played an increasingly important part in the many applications of electronic technique in measurements generally, in radio, in research, and in industrial and medical instruments. To my personal knowledge this new book is the only attempt at the mammoth task of producing an encyclopaedia of cathode-ray oscilloscopes, as well as applications in all fields of research where this most versatile device can be employed.

The book was first published in 1950, but this second edition represents a complete revision of the earlier work, made necessary because of the tremendous expansion in technological research involving the cathode-ray oscilloscope. The work is divided into five main sections. The chapters are very detailed. Thus in the first section there are chapters on the basic characteristics of cathode-ray tubes, the principles of focusing and deflexion, deflexion systems and spot displacement, and the screens of cathode-ray tubes. There is a fair presentation of the practice of the subject with correlation with the appropriate theory. The bibliography is included in a separate appendix at the end of the book, and is reasonably up-to-date, reference being made to a number of scientific papers published as late as 1958. The chapters in the second section are on the basic oscilloscope, vertical and horizontal amplifiers, time bases, synchronization, power-supply circuits, auxiliary equipment and accessories, oscilloscope circuit analysis and maintenance, and special purpose cathode-ray tubes. The latter chapter is of particular value as it deals with many new subjects, e.g. flying-spot cathode-ray tubes, storage tubes, etc. The applications section (Section 3) is very thorough, including basic pulse measurement and observation, phase and frequency measurements, audio-frequency circuit testing, transmitter testing, visual aligment of a.m., f.m. and television receivers, observation of voltage wave-forms of television receivers, electrical tests in connexion with engineering, medical and scientific application (124 pages), and oscilloscope photography. This section is probably the most valuable in the book. Section 4 deals particularly with the use of wave-form patterns, but also deals specifically with square-wave testing of *RC*-coupled amplifiers and networks, and includes drawings of many hundreds of wave-form patterns of real value to the user of cathode-ray oscilloscopes. Section 5 gives the specification and circuit details of more than a hundred commercially available oscilloscopes, including many of the special instruments, namely travelling-wave oscilloscopes. One aspect particularly pleasing to the reviewer is the inclusion of many British instruments.

As a work of reference the new encyclopaedia is a 'must' for every laboratory wanting to be well-informed on the subject of cathode-ray oscilloscopes and their uses. It is well printed and illustrated.

DENIS TAYLOR

Thermo-electricity

Applications of Thermoelectricity *by* **H. J. Goldsmid.** *Methuen & Co.: London. John Wiley & Sons: New York. 1960. 118 pp. 10s 6d.*

Claimed to be the first short introductory book on thermoelectricity by a specialist, this is a recent addition to the publisher's well-known series of monographs on physical subjects. The work is designed to a large extent for newcomers, and succeeds quite well in the limited space available. Beginning at the Kelvin relations, the treatment proceeds through theory to discussions of the properties, figure of merit, and selection of semiconductors. There is then an account of semiconductor alloys and of the preparation and evaluation of materials. The final chapters deal with applications of the Peltier effect and with thermo-electric generation.

The index is far from adequate, and some of the mathematical setting could be improved, but on the whole the presentation is good.

K. J. SPARE

Photo-sensors

Lichtempfindliche Bauelemente für die Automatisierung *by* **Paul Goercke.** (*In German*). *R. v. Decker's Verlag, Hamburg. 1960. 312 pp.*

This is a very good little book containing a wealth of useful and up-to-date information. Its layout is clear and systematic—sometimes perhaps a bit too systematic for the comfort of the author as well as the reader (as in the definition of the scope of book, numbering tables as 'Abbildung' etc.). It is the more disappointing that the literature references are not collected at the end of the chapters or of the book, but strewn all over the bottoms of the pages. This makes the finding of back references unnecessarily difficult, as no hint is given on which page to look for them. I found that carefully chosen practical examples showed very clearly how the knowledge and information contained in the foregoing chapters can be used in the solution of set practical industrial problems of control. The book should be on the shelf of any student or engineer dealing with photo-sensitive devices.

G. A. VESZI

Literature Received

Silicon Photovoltaic Cells and the Utilization of Solar Energy *by* **C. A. Escoffery** *and* **Werner Luft.** *International Rectifier Co., California. 1960. 26 pp.* ★ 701

Comparison Debug-A Routine for Mercury *by* **A. R. Curtis.** *U.K.A.E.A. 1960. 4 pp. 1s. 2d.* ★ 702

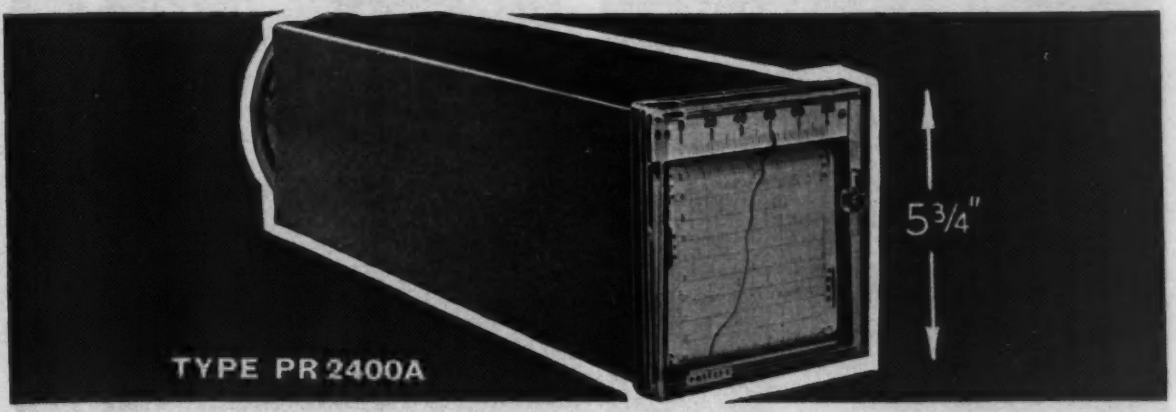
Bulletin of Special Courses in Higher Technology. *London and Home Counties Regional Advisory Council for Technological Education. 1960. 127 pp.* ★ 703

Cathode Ray Tube Memory of the High-Speed Electronic Computer of the U.S.S.R. Academy of Sciences. V. N. Lant *and* **L. A. Lyubovich.** *Pergamon Press Ltd. 1960. 90 pp. £1 15s.* ★ 704

★ Circle the relevant number on the reader information card facing page 182 for further information.

PHILIPS

MINIATURE RECORDER



FEATURES Small panel space of 144 x 144 mm (approx. 5¾" x 5¾") · Reliable null-balancing potentiometer system · Easily interchangeable ranges · Transistorized plug-in amplifier with printed wiring · Unique chart-winding system · High indicating speed and critical damping · Scale calibration for mV or all conventional thermocouples · Completely mains operated.

RECORDING SECTION Strip chart, width 100 mm, length approx. 9 m. The chart is wound into an exchangeable casette. Visible length of 100 mm. After opening the door the chart can be pulled out over a length of 80 cm. Chart returns automatically into the casette.

CHART-SPEED With built-in gear box 3 different speeds can be selected: 10, 20 and 60 mm/h. Can be supplied with electro-mechanical clutch so that by means of external switch, chart movement can be accelerated by a factor of 60.

Miniature mV-Recorder

MINIMUM SPAN 5 mV · MAXIMUM SPAN 250 mV
ACCURACY 0·5%; the accuracy can be maintained after exchange of range box.
REPRODUCIBILITY 0·2% of span · SCALE LENGTH 100 mm.
STABILITY 10% mains variations have an influence of less than 0·1%
BALANCING SPEED Less than 1 sec. for full scale deflection; damping critically adjustable.

RECORDING With flexible capillary stylus supplied from sealed ink container mounted under measuring carriage. Line thickness approx. 0·3 mm.

CONSTRUCTION Sheet-metal case in grey hammertone with all plastic door. Front dimensions 144 x 144 mm; depth 510 mm; panel opening 138 x 138 mm. (5¾" x 5¾"—20"—5½" x 5½").

PRODUCT OF PHILIPS, EINDHOVEN, HOLLAND

This photograph shows the lighter weight and compact size of the plug-in transistorized amplifier.

SOLE DISTRIBUTORS IN U.K

RESEARCH & CONTROL INSTRUMENTS LTD

Instrument House 207 Kings Cross Road · London · W.C.1.

Telephone: Terminus 2877

(RCL0009)

all in one

Consistent accuracy, small size, mechanical ruggedness and an efficiency unimpaired by extreme conditions—all these, in every synchro made by Ketay.

✳ As a result of recent design developments, the latest Ketay synchros are able to detect shaft movement of as little as three minutes, or 1/7,200 of a revolution! In achieving this standard of accuracy—and an unfailing reliability—an important part is played by the through-bore construction which is a vital characteristic of these synchros.

✳ They are small and light enough for use in many critical applications where size and weight must be minimal. The smallest in the current range—which covers sizes 11 to 23, with size 08 soon to be in production—has an outside diameter of just 1.1″ and weighs only 4.0 ounces.

✳ This valuable miniaturisation involves no sacrifice of mechanical ruggedness—with stainless steel housing and encapsulated windings, Ketay synchros will perform efficiently and consistently under most severe conditions of impact or vibration.

✳ They also maintain the same high level of performance in extreme temperatures. Generally, the operating range is −55°C to +85°C, but recent progress has enabled even these figures to be bettered; a new Ketay series of synchros capable of working at 125°C is already available and developments are in hand to improve this figure to 200°C.

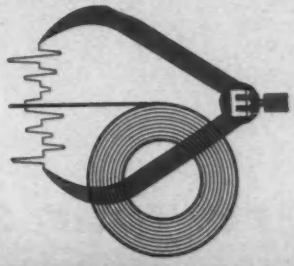
✳ Ketay synchros have an outstandingly high resistance to moisture and other climatic conditions; this is afforded by stainless steel housings, shafts and bearings, hermetically sealed windings and other design features.

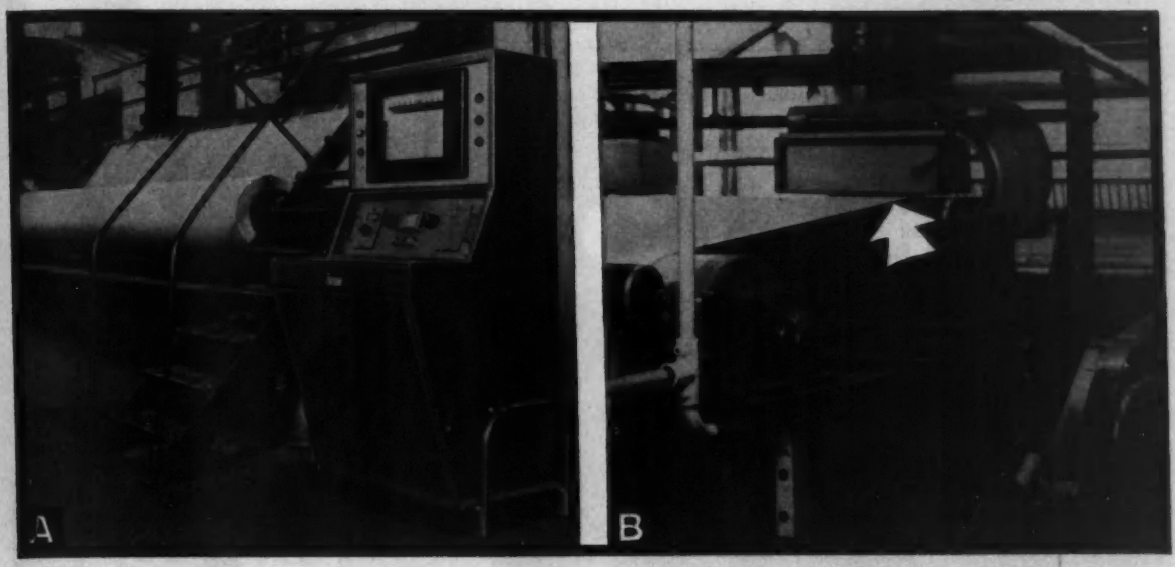
Every one of these units embodies the highly specialised knowledge of Ketay engineers who are continually at work on environmental and accuracy problems connected with servo components and systems. Their very considerable experience and skills, backed by superior development facilities, are available as a service of which all plant designers and engineers are invited to make full use.

Ketay

KETAY LTD · EDDES HOUSE · EASTERN AVENUE WEST · ROMFORD · ESSEX
TELEPHONE: SEVEN KINGS 6050
Overseas Sales Organisation: Plessey International Limited · Ilford · Essex Tel: Ilford 3040

Step up your plant efficiency





(Photographs by courtesy of the Bowaters Organization and I.C.I. Ltd.)

EKCO Nucleonic Gauges provide an ideal solution to many of the problems connected with *quality control* of materials produced by continuous-flow processes.

They give continuous, accurate measurement of thickness or weight per unit area, at the earliest possible stage of manufacture, without contact with materials.

EKCO Reliability. All EKCO Nucleonic Gauges are built to maintain their high standards of efficiency and to give easy, *low-cost*, trouble-free operation. They are used by leading industries the world over.

A. *An Ekco Automatic Standardisation Gauge shows prominently in this front view of the dry end of a 280 in. Fourdrinier Machine producing newsprint.*

B. *Two measuring heads, one on each side of the sheet, are employed in this Ekco Nucleonic Gauge installation. The machine is a Bridges 3-bowl calender, producing PVC coated fabric in one of the largest factories manufacturing leather cloth in Great Britain.*

Because Ekco Nucleonic Gauges work to exceptionally low limits of tolerance they:—

1 SAVE EXTENSIVELY ON MATERIALS

2 GREATLY REDUCE START-UP TIME

3 GIVE IMPROVED PRODUCT UNIFORMITY

One of our Technical Representatives will gladly call to discuss how Ekco Nucleonic Gauges can step up your plant efficiency.

EKCO nucleonic gauges

EKCO ELECTRONICS LTD · SOUTHEND-ON-SEA · ESSEX · SOUTHEND 49491

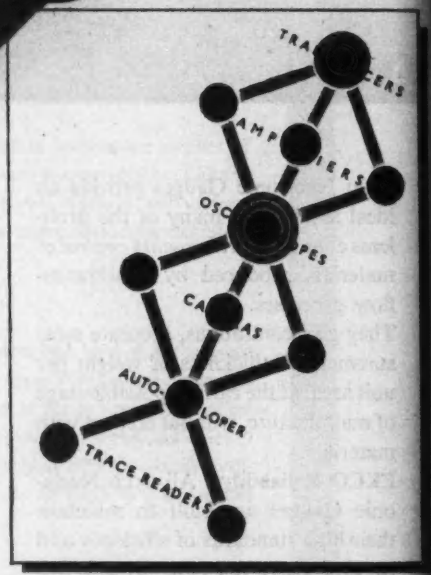
WP6510

The G243

Are your seatings hot?

This Flush Diaphragm Resistance type Pressure Transducer is temperature compensated and has been specially developed for engine indicating and similar work where records at high frequencies are required under hot conditions.

Pressure range: 260—6,000 lbs/sq inch
Fixing thread: 18 mm × 1.5 mm or ¼" B.S.P. ¼" long
Weight: 6 oz. approximately



SOUTHERN Instruments

Send now for descriptive catalogue and let us have details of your application.

SOUTHERN INSTRUMENTS LIMITED CAMBERLEY SURREY

STC in control

at DOUNREAY : BRADWELL
CALDER HALL : BERKELEY
CHAPEL CROSS : LATINA (Italy)

- Telemetering Systems
- Alarm Annunciation Systems
- Operational Telephone Systems
- Miniaturized Direct Wire Control Systems

STC design, manufacture and install for the Nuclear Power Industry, all types of Remote Control and Indication Systems, Telecommand Systems, Indication Diagrams, Automatic Temperature Scanning Equipments, Data Logging and Printing Systems, etc.

ELECTRONIC SYSTEMS GROUP

Standard Telephones and Cables Limited

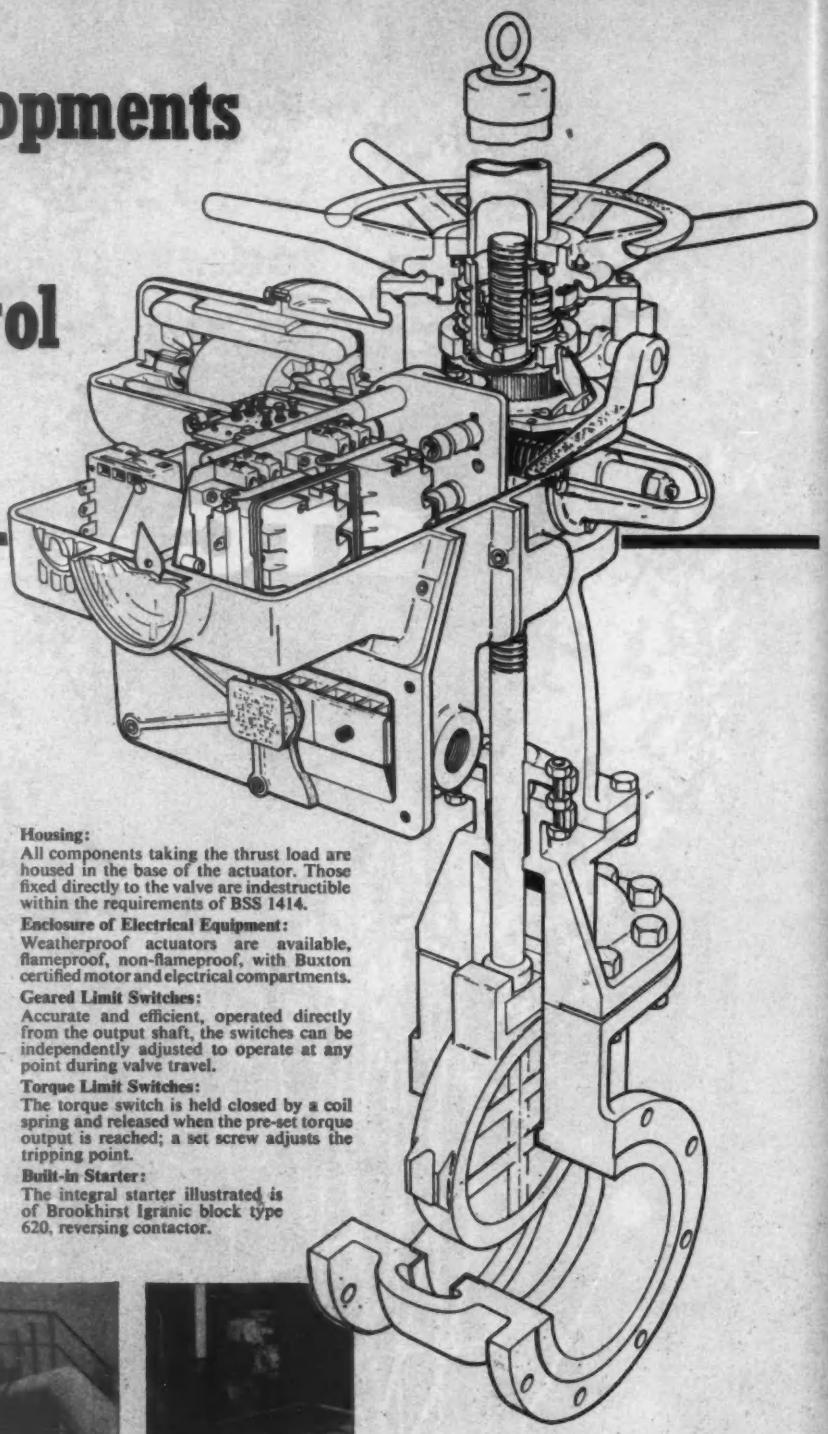
Registered Office: Connaught House, Aldwych, London W.C.2.

INSTRUMENTATION AND CONTROL DIVISION

PROGRESS WAY GREAT CAMBRIDGE ROAD ENFIELD MIDDLESEX

60 SR

New developments in Rotork valve control



Valve manufacturers and users all over the world have helped Rotork develop their new series of electric actuators — the 'A' range. Such practical advice, coupled with Rotork's comprehensive experience of valve control, ensures that the 'A' range offers the most competent method available for automatically controlling any size or type of valve from any distance.

An entirely new manufacturing and selling organisation has been created to keep pace with the growing international demand for Rotork actuators. Highly competitive prices and good deliveries on a world-wide scale are assured by the overseas manufacturing and sales facilities now available in West Germany, France and Italy to augment U.K. production; as well as offices or agents in Holland, Switzerland, Australia, Canada and the Arabian Gulf.

A booklet covering every aspect of the Rotork 'A' range of actuators is available on request.

Outstanding features of the Top Handwheel 'A' Type Actuator illustrated are:—

Motor:
Squirrel cage, Stator/rotor unit, half hour rated and built to BSS 2613. Available with class 'A', 'B' or 'E' insulation.

Input Shaft:
Motor, worm and torque measuring spring pack are all on this common shaft, which slides in direct proportion to the torque transmitted to operate the torque switch to shut off the motor.

Housing:
All components taking the thrust load are housed in the base of the actuator. Those fixed directly to the valve are indestructible within the requirements of BSS 1414.

Enclosure of Electrical Equipment:
Weatherproof actuators are available, flameproof, non-flameproof, with Buxton certified motor and electrical compartments.

Geared Limit Switches:
Accurate and efficient, operated directly from the output shaft, the switches can be independently adjusted to operate at any point during valve travel.

Torque Limit Switches:
The torque switch is held closed by a coil spring and released when the pre-set torque output is reached; a set screw adjusts the tripping point.

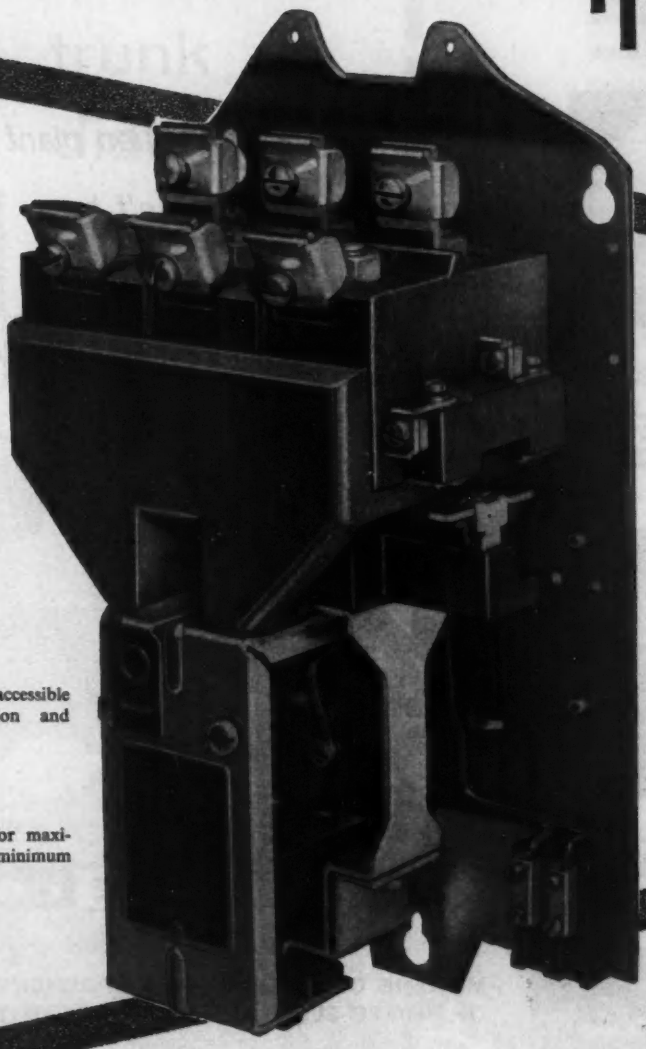
Built-in Starter:
The integral starter illustrated is of Brookhirst Igranic block type 620, reversing contactor.

(Left and centre) Two typical overseas petroleum installations using Rotork actuators. (Right) Rotork actuators installed at the Vickers-Armstrong Hydraulic Test Plant.

Rotork have a controlling interest in all types of valves!

ROTORK ENGINEERING COMPANY LIMITED of BATH, ENGLAND. Tel: 64558

LDN Contactors and Contactor Starters 'Type MK'



MK3 Contactor

★ Complies with relevant British Standard Specification (frequent duty).

★ Modern design gives robust yet simple construction combining reliability in service with exceptionally long operating life.

★ All parts readily accessible for easy installation and inspection.

★ Silvered contacts for maximum life and minimum maintenance.

★ Clamp type solderless terminals for rapid connection.

★ Contact carriers moulded from arc resistant, non-hygroscopic material with internal phase barriers.

★ Complete range of thermal overload units available.

★ Can be supplied as shown or fitted in wall mounting steel or cast cases.

MK Contactors
are available from stock in 15, 25, 60 and 100 ampere ratings for a.c.

Control Coils
can be supplied for a wide range of a.c. and d.c. voltages.

Auxiliary Contacts
can be fitted to all sizes of contactors.

For long and trouble-free operation specify L.D.N. Contactors.

Write for Technical Leaflet LS 2510

LANCASHIRE DYNAMO NEVELIN LTD

(SWITCHGEAR DIVISION)

HURST GREEN, OXTED, SURREY. Telephone: OXTED 3361. Telegrams: NEVELIN OXTED

A Member of the Metal Industries Group of Companies

S5

RADIOVISOR
EST. 1927

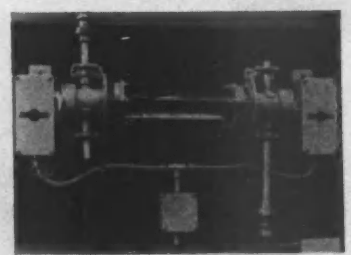
* P.E control

Event Recorder

A permanent record of 'ON' 'OFF' time associated with any process or operation. Idle machine time, duration, over-load periods, etc, are recorded on a 24-hour circular chart revolving at 1" per hour. The recording stylus is operated by a built-in electro-magnetic movement actuated by an external micro switch, relay or other contact-making device.

Electronic Level Control

Radiovisor manufacture many different types of electronic level control so that from their range a unit will be found suitable for any material or liquid. Liquids in tanks, solids in hoppers or powders in packets—there is a level control for the job.



Automatic Turbidity Control

Liquids are continuously observed for clarity and any changes in opacity recorded. In addition to a continuous record, a warning device may be actuated or some other desired function performed if the clarity of the liquid changes to a pre-determined value. The photo-electric viewing chamber may be an integral part of a main feed line, or incorporated into a by-pass sampling system.

There isn't a production plant anywhere that couldn't be made (or hasn't been made) more efficient, more economical by the use of Radiovisor Photo-electric and Electric Controls

* P.E. is photo electric

It costs nothing to consult us—
We have over thirty years' experience

RADIOVISOR P.E control

MAKERS OF THE MOST COMPREHENSIVE RANGE OF PHOTO-ELECTRIC CONTROLS IN THE WORLD

Standard photo-electric equipment includes:—

Flamestat Flame Failure Control • Smoke Detector Fire Alarm Sequence Control • Counting and Batching Unit • Invisible Ray Burglar Alarm • Turbidity Equipment • Hopper and Bunker level Control • Print Registration • Photo-electric Safety Guard • Factory Lighting Control • Automatic Radiation Pyrostat • Automatic Door Opening • Industrial Smoke Density Indicator and Alarm

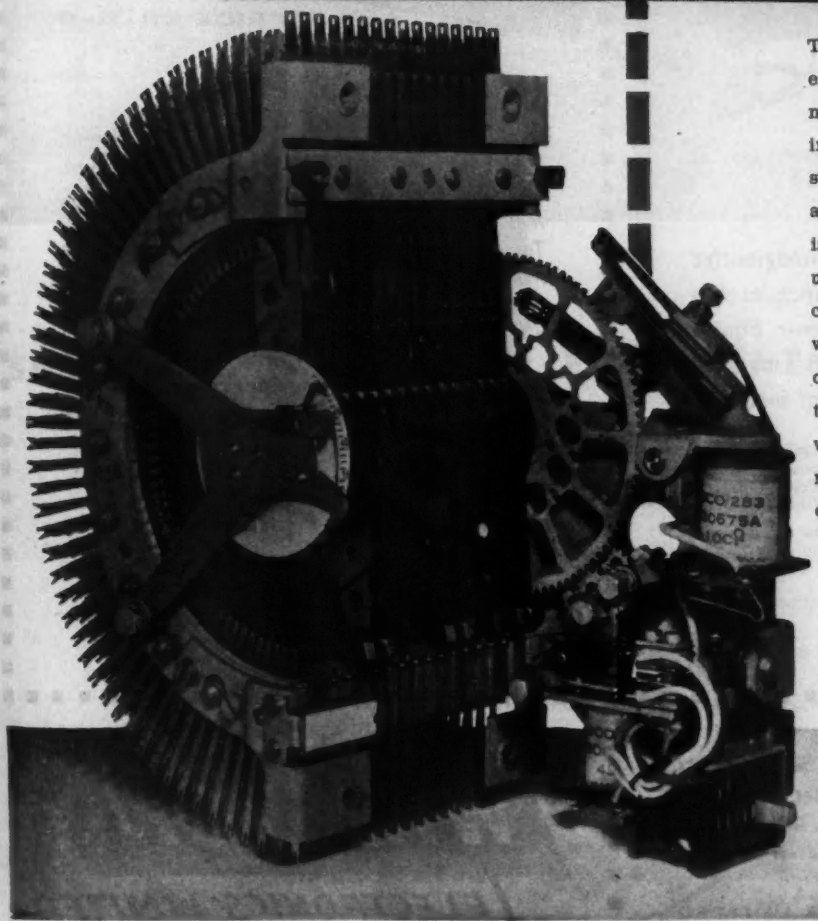
RADIOVISOR PARENT LIMITED, Stanhope Works, High Path, London, S.W.19
Telephone: CHErrywood 3351 Telegrams: Radivisor, London, S.W.19

for subscriber trunk dialling...

AEI

The success of Subscriber Trunk Dialling depends to a large extent on the provision of a grade of service on long distance routes similar to that enjoyed in local exchange switching. To achieve such service economically it is essential that a high outlet availability is provided at trunk switching centres, coupled with the facility for flexible allocation of outlets.

high speed motor uniselector



The AEI Motor Uniselector was expressly designed to meet these needs and its outstanding success in operator controlled trunk switching in the United Kingdom and many other parts of the world is a guarantee of its equal success under subscriber trunk dialling conditions. High search speed, twin wiper contact, low vibration and lack of microphonic noise are some of the further features which combine with the unique reliability of the mechanism to make it the obvious choice for modern trunk switching.

Associated Electrical Industries Limited
Telecommunications Division
WOOLWICH, LONDON, S.E.18
formerly the Telecommunications Division of Siemens Edison Swan Limited

TA4196

WINSTON DECADE CAPACITOR BOXES

S-BAND SPECTRUM ANALYSER

Frequency Range 2640/3200 Mc/s.
Absolute Frequency Measurement ± 1.5 Mc/s.
Relative Frequency Measurement ± 250 Kc/s.
Sensitivity minus 85db relative to 1mW at the input.

DC/AC VALVE VOLTMETER

Ranges:
Range in balanced D.C. position (centre zero): ±2.5V., ± 7.5V., ± 25V., ± 75V., ± 250V., ± 750V.
Range in plus or minus D.C. position (left-hand zero): 5V., 15V., 50V., 150V., 1500V.,
Range in A.C. position: 5V., 15V., 50V., 150V. Accuracy 3%.

PRICE £11-11-0

SPECIFICATION

Range	.001 mfd to 1.11 mfd.
Zero Capacitance	50 pf.
Accuracy	± 5%
Maximum Voltage	750V D.C.
Terminals	Screw Type
Mounting	Metal case and panel
Finish	Blue hammertone case, Black and silver photoetched panel.

The practical application of imaginative thinking, based on tested principles has produced, in Winston Electronic Equipment, a range of instruments that matches the rapid advance of industrial methods.

SUB-CONTRACT. Full sub-contract facilities for the development and manufacture of Electronic Equipment and Sheet Metal Work. Coil Winding Facilities. A.I.D. and A.R.B. Approved.

Write for full particulars of facilities available and catalogue of Instruments and Electronics to Dept. C.

IN ADDITION TO THE ITEMS FEATURED HERE THE WINSTON RANGE OF ELECTRONIC EQUIPMENT INCLUDES:—

Semi Decade Oscillator
Resistor Boxes
"X" Band Spectrum Analyser
"L" Band Spectrum Analyser
"L" Band Signal Generator
Temperature Controller
Shockley Diodes
Sub-Contract Facilities
Sheet Metal Work
Standard Metal Cases
Transistor Curve Tracer

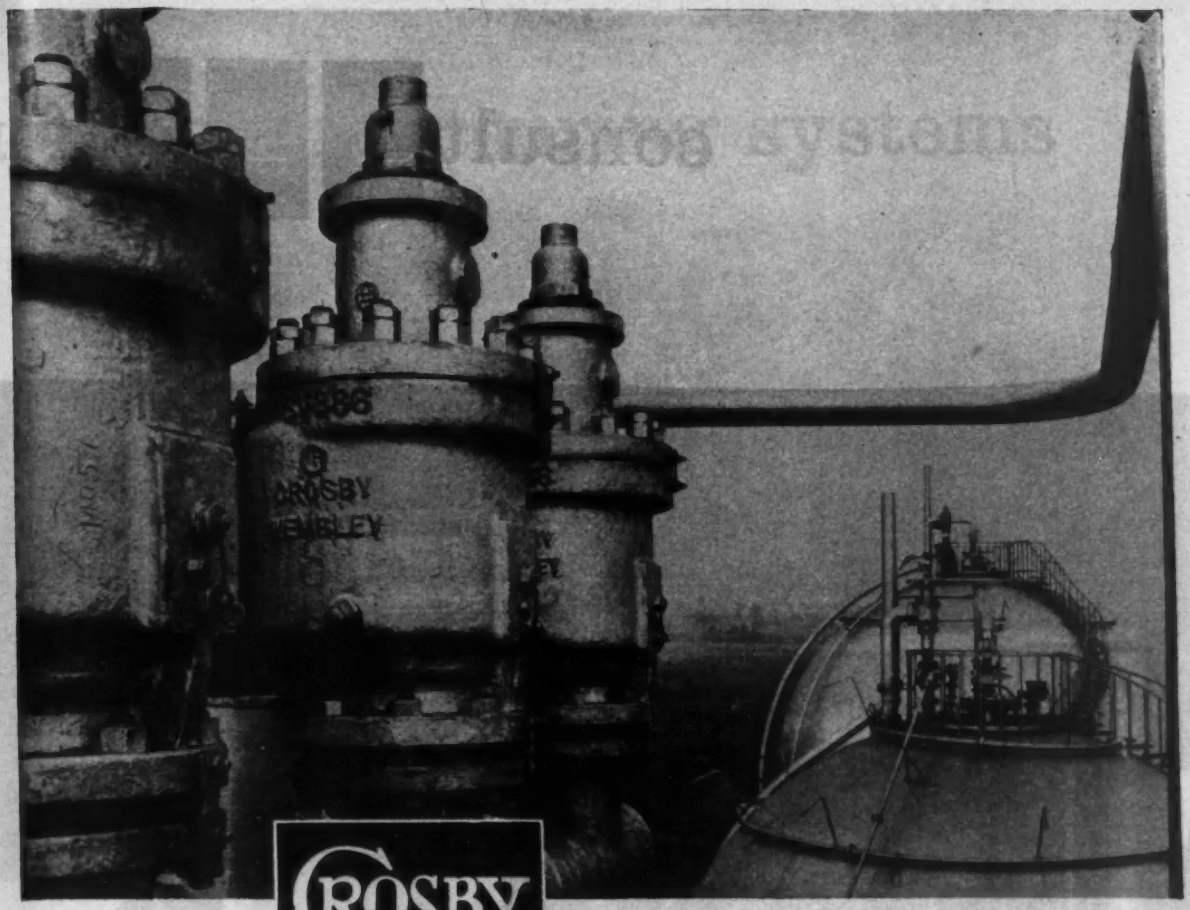
Winston Main Agents and Service Centres

HIRD-BROWN LIMITED,
244 Marsland Road, Sale, Cheshire
Area: Lancashire, Cheshire, Yorkshire and North Wales

HAWNT & COMPANY LIMITED,
112/114 Pritchett Street, Birmingham, 6
Area: Worcester, Warwickshire, Herefordshire, Northamptonshire, Leicestershire, Staffordshire, Derbyshire, Nottinghamshire, Lincolnshire and Shropshire

WINSTON ELECTRONICS LIMITED

INSTRUMENTS — COMPONENTS — PRODUCTION FACILITIES
GOVETT AVENUE · SHEPPERTON · MIDDLESEX
Telephone: Walton-on-Thames 26321/5
Telegrams: Winston, Shepperton



CROSBY

MASONEILAN

SHELL USE EQUIPMENT AT SHELL HAVEN

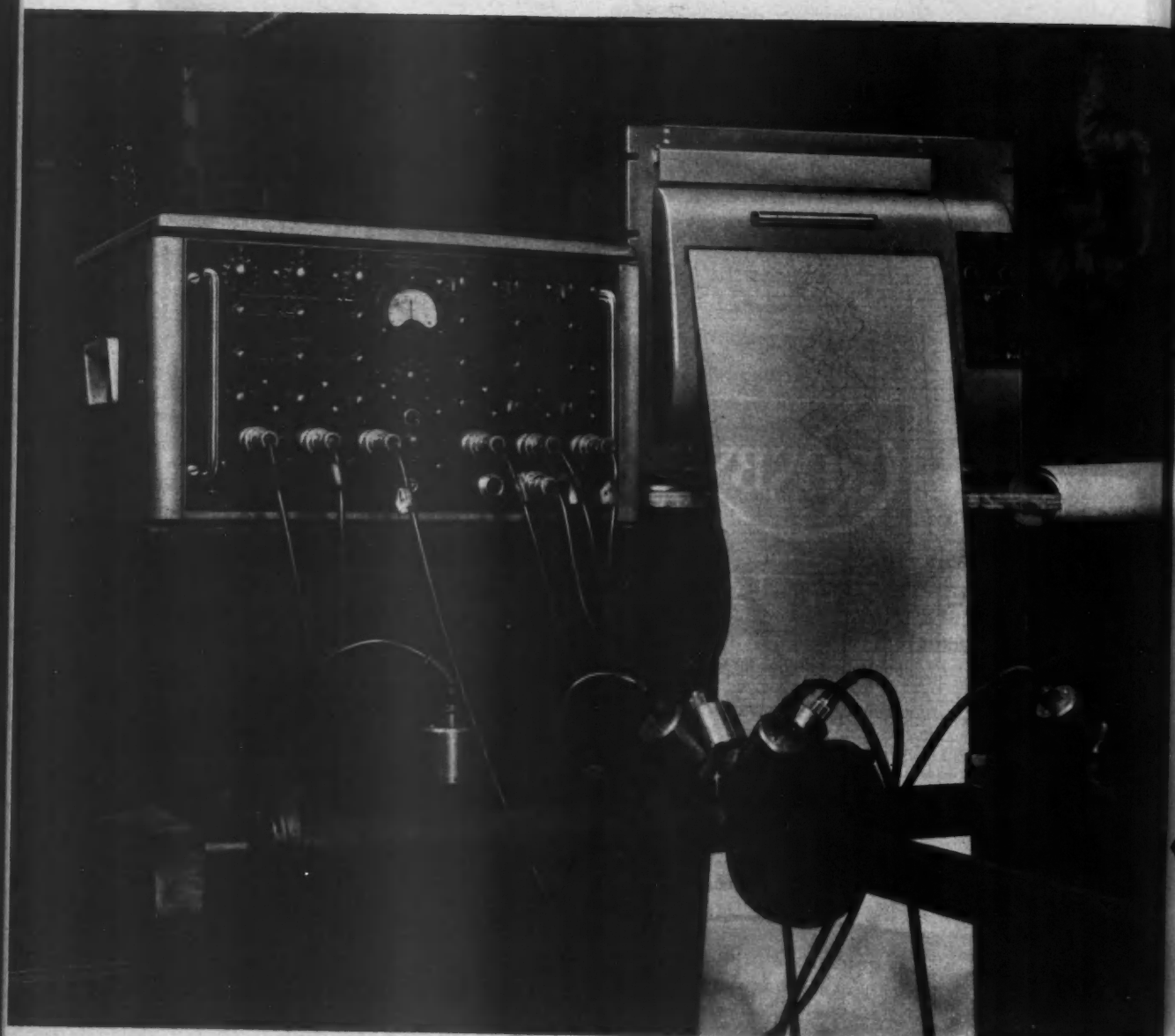
Illustration shows three of four 6 x 8 Crosby Relief Valves together with Masoneilan Liquid Level Transmitters mounted on each of three Butane Storage Horton Spheres at Shell Haven. These relief valves protect the tanks from overpressuring. The level instruments transmit the level of liquid Butane in the Spheres back to the Receiver in the control room. The reliability of this equipment is thus exemplified once again by one of the major oil companies of the world.

IMPORTANT ANNOUNCEMENT
Details are now available of the Crosby portable self-contained Safety Relief Valve Test Stand for Works or Site test purposes.

CROSBY VALVE & ENGINEERING CO. LTD., CROSBY WORKS, WEMBLEY, MIDDLESEX
Telephone: Alperton 2311

CHWR/1960/1a

consult N E P ford



for dynamic measuring systems

Pressure Transducers are suitable for measuring high frequency pressure variations in a wide range of fluids at temperatures up to 200°C.

Carrier Amplifiers and Detectors provide a simple method of amplifying low level signals from resistance strain gauge and inductance type transducers.

Direct Writing Galvanometer Recorders present a visible and measurable record of up to 36 signal channels within seconds of the event. The range of interchangeable galvanometers includes units for use at 5000 cycles per second to units sensitive enough to work directly from strain gauges and thermocouples.

Experience is at your service. We can supply the individual components or design and construct the complete system.

NEP Pressure Transducers, Multichannel Carrier Amplifier and Direct Writing Galvanometer Recorder being used for the determination of transient-pressure changes in complex engine exhaust systems at the Department of Mechanical Engineering, University of Liverpool.

New Electronic Products Ltd

MAKERS OF SCIENTIFIC MEDICAL AND INDUSTRIAL INSTRUMENTS

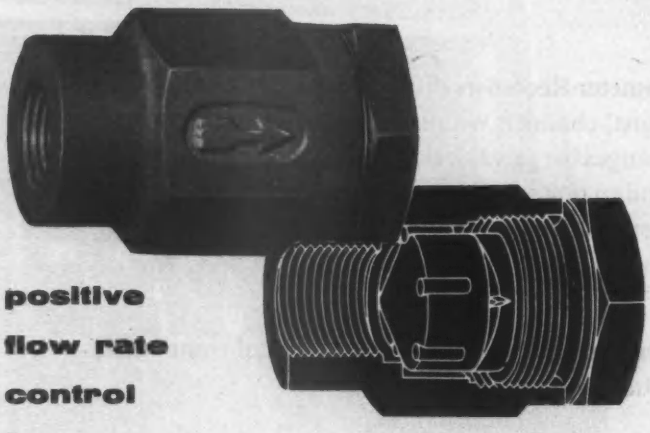
Suppliers of recording instruments and systems to the aircraft and G.W. industries, Government establishments, Admiralty, etc., A.I.D. approved

Head office and works: 360 Kennington Road London SE11 RELiance 5161

BIRFLO controls

for positive and precise regulation of hot or cold water, light oils and air.

Constaflo CONTROL

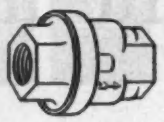


positive flow rate control for water-oil-air

The "Constaflo" is designed to deliver one set rate of fluid flow regardless of variable inlet pressures between 10-200 lbs. p.s.i. It automatically measures a predetermined amount of flow regardless of variable pressures and eliminates unnecessary waste. A fixed rate of outlet flow is assured as the flow is regulated in direct proportion to the inlet pressures exerted against the diaphragm. The "Constaflo" is available in three sizes, to cope with rates of flow from ·1 to 7 g.p.m., it is of high quality non-corrosive bronze, and is both durable and reliable. The "Constaflo" can be used with a timing device for measuring quantities, subdues pressure hammer and flow surges, and reduces maintenance of appliances and equipment.

The "Constaflo" is one of seven Birflo controls, each designed to solve flow problems.

Made under licence from the Hayes Manufacturing Co., Erie 6, P.A.

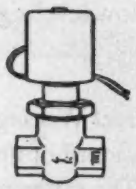


MULTI CONSTAFLO

An accurate metering valve for flow rates up to 86 g.p.m. Sizes ¼" to 2".

TRUFLO

For positive flow-rate control with minimum (0·1 g.p.m.) or maximum (40 g.p.m.) limits.

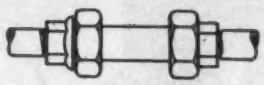


FLOMAX

A solenoid valve for maximum flow rates. Sizes up to 1¼" B.S.P.

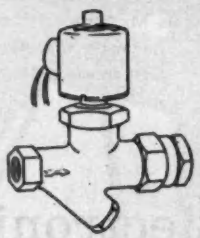
FLOMITE

A direct action solenoid valve for small flow and volume control. Sizes ¼" and ⅜".



STRAITFLO

A straight line strainer, installed in the supply, having the entire strainer area within the flow way itself. Sizes up to 1¼"



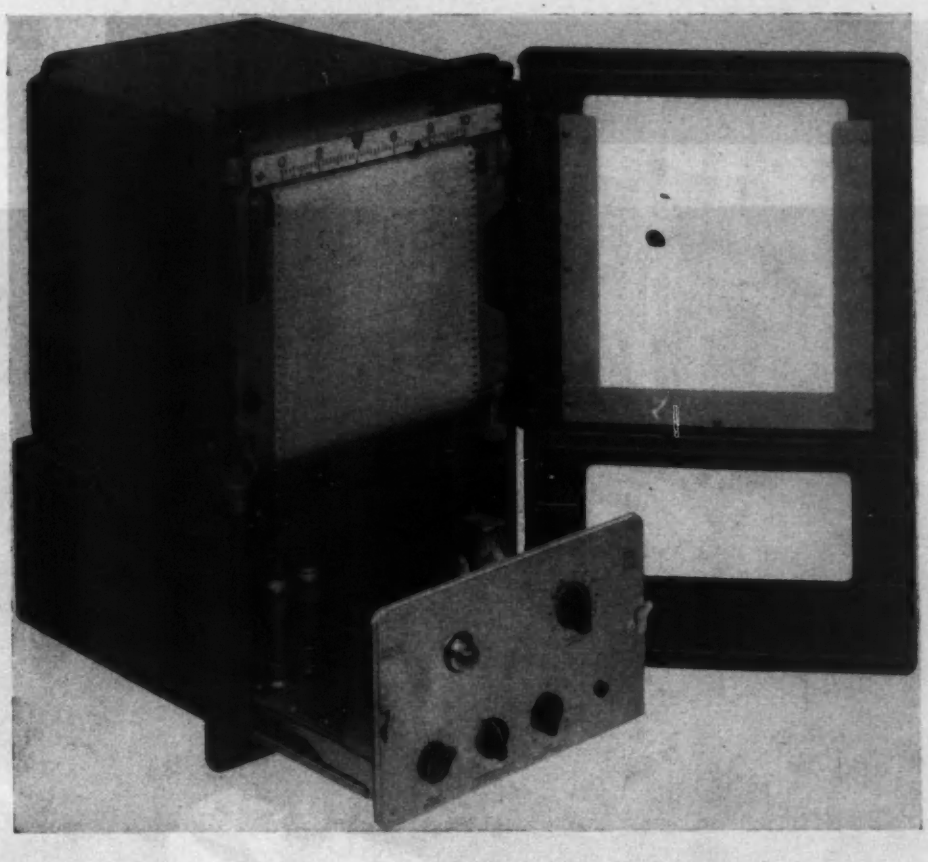
FLOMETRIC

Solenoid valve combining consistent flow control with filter protection. Flow rate from ¼" g.p.m. to 4½ g.p.m.

product of **BIRFIELD** **GROUP** experience and resources

Fully informative leaflets on all the Birflo Controls are available on request.

Enquiries to **LAYCOCK ENGINEERING LIMITED** MILLHOUSES • SHEFFIELD 8



Speedomax Type H with Series 60 additional controls integrally mounted

Entirely new, and quite outstanding is the latest L & N introduction-Series 60 Electronic Control. It provides single-action (proportional), 2-action (proportional and reset) and 3-action (proportional, reset and rate) control.

It is a compact unit, all elements being readily accessible for servicing and all major components plug-in, and when supplied with our latest Speedomax Type H potentiometer forms an integral part of the main instrument requiring panel space of only 17⅝" x 11" x 11", the unit pulling out like a drawer. This control is also marketed as a separate unit.

It is lower in cost than any comparable electronic potentiometer available to-day.

Send now for descriptive literature and as choice of control depends on your product and your process, please outline briefly your application.

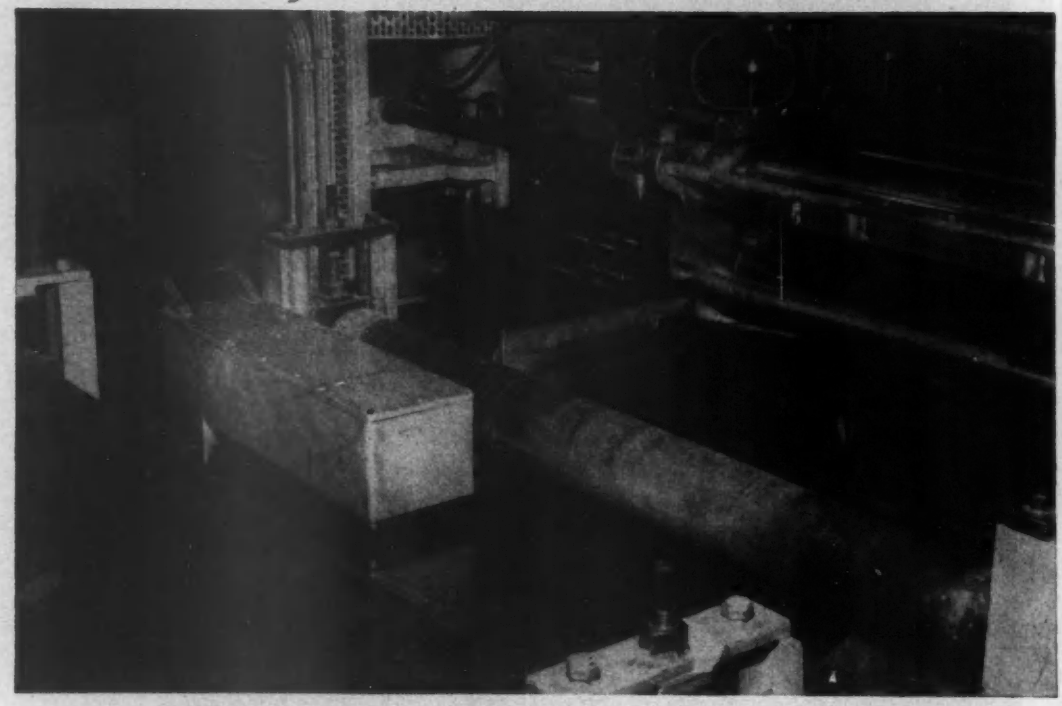
INTEGRA, LEEDS & NORTHRUP LTD.

183, BROAD STREET, BIRMINGHAM, 15

Telephone: MIDLAND 1453/4 Telegrams: FLOMETER, BIRMINGHAM

British made in Birmingham

DAVY-UNITED **instruments** IN OPERATION



Radiation thickness Gauges

MEASURING THICKNESS OF STEEL STRIP TO AN ACCURACY OF ·00005"

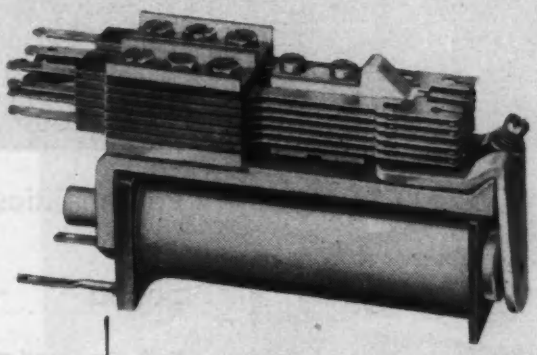
A twentieth of a one-thousandth part of an inch, (.00005" if you prefer the figures), is just about a fortieth of the thickness of the average human hair. Today, measurement to limits as fine as this can be made on the thickness of rolled steel strip while it is actually being processed—continuously and without any necessity for contact with the metal itself. Radiation type gauges, using radio-active isotopes, capable of such consistent precision under the hard operating conditions of a steelworks, are amongst a wide range of control instruments developed by Davy-United. They include A.G.C., a system for controlling automatically the thickness of strip produced on both hot and cold mills, which rolling plants in such countries as America and Japan are now adopting.

instrumentation by DAVY-UNITED

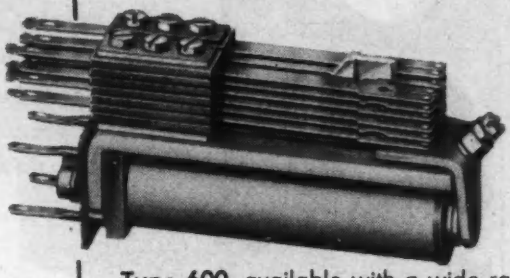
DAVY AND UNITED INSTRUMENTS LIMITED, DARNALL WORKS, SHEFFIELD 9

372/DU

RELAYS

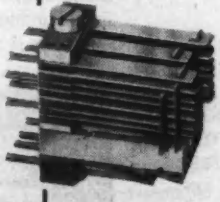


Type 3000, available with a wide range of contact combinations, coil resistances and slugs.
Tropical finish type approved to RCS 161.
Standard finish for telecommunications applications in temperate climates.



Type 600, available with a wide range of contact combinations and coil resistances.
Tropical finish type approved to RCS 161.
Standard finish for telecommunications applications in temperate climates.

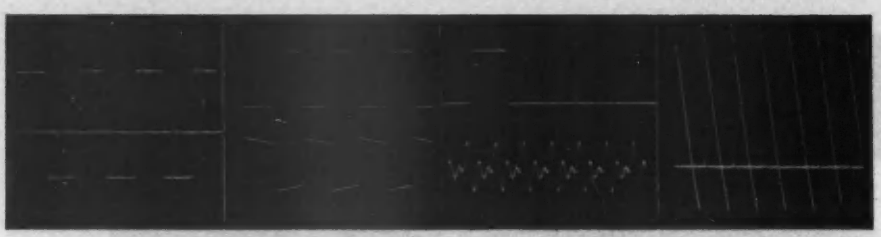
Remanent (magnetic latching) versions of type 3000 and type 600 are also available.



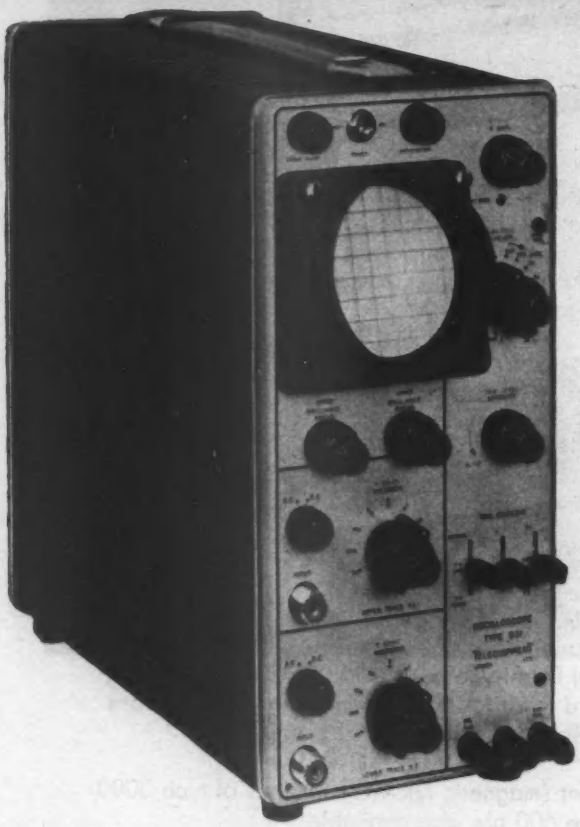
Cubic Inch, combining high speed and sensitivity in a new miniature design with twin contacts of the well-proven form used on the type 3000 relay.

THE PHŒNIX TELEPHONE AND ELECTRIC WORKS LIMITED,
THE HYDE, LONDON, N.W.9. *Telephone* COLINDALE 7243

TELECOMMUNICATIONS
PLUGS · LEVER KEYS · CABLES
FUSE MOUNTINGS · AMPLIFIERS
CONTROL PANELS · MOULDINGS
COUNTERS · PLUNGER SWITCHES
MAGNETIC AMPLIFIERS · RELAYS
SATURABLE REACTORS · JACKS
TRANSFORMERS · INSTRUMENTS
CORDS · INTERNAL TELEPHONES
TRANSISTOR INVERTERS · BELLS
PROTECTORS · WIRES · BUZZERS



D31

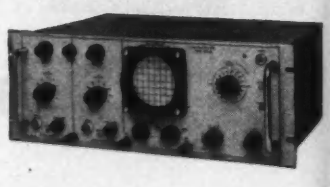


Potentialities per pound

Both per £ and per lb., each Serviscope* offers greater flexibility, accuracy and reliability than any oscilloscope of comparable specification. A radical reassessment of design and production techniques has enabled smaller, lighter, instruments with many improved features to be offered giving a far higher performance than their low price would suggest.

Weight: 26 lbs. **£95**

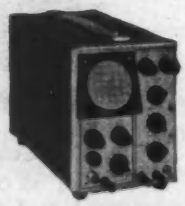
D31R



Electrically identical, but designed for mounting in standard 19½" racks.

D.31 double beam Serviscope*

D. C. amplifiers and slow speed time base (down to 5 sec/cm if necessary) are eminently suitable for servo work and similar applications. Fast rise time (.06 μ sec) and high writing speed (10 cm/μ sec at maximum expansion) are essential for any work dealing with fast pulses or TV waveforms. The unique triggering arrangements enable complex waveforms to be examined in detail with complete accuracy of synchronisation. At this moment the D.31 is in use in the diverse fields of computer development and servicing, radar equipment, telemetering applications, closed circuit and broadcast TV, automatic telephone equipment . . . and is proving itself ideally suited to laboratory work where an oscilloscope has, of necessity, to be somewhat of a Jack of all trades.



S31

S.31 single beam oscilloscope has the same specifications with a single beam display. The original, highly successful, 'Serviscope'.

Weight: 16 lbs. **Price: £75**

* *'Serviscope' is the registered trade mark of Telequipment Ltd.*

TELEQUIPMENT

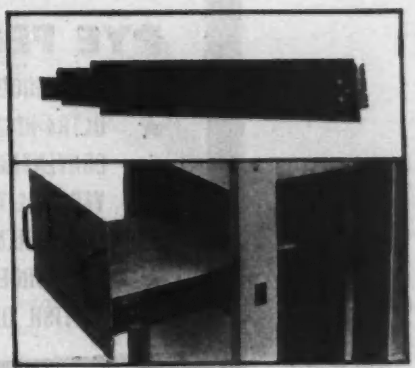
Telequipment Limited, 313 Chase Road, Southgate, London, N.14. Tel: Fox Lane 1166

Here a pair of Imslides (IMS 500/19) are shown carrying well over 300 lb. (135 kg.): the Imslide Technical Service will be pleased to give recommendations wherever loads of this order are proposed

IMslide

a new approach to telescopic runner design - *combines all the features*

Imhofs new telescopic mountings are introduced to meet the specific needs of the electronics industry. They combine lightness, maximum strength, lowest possible friction characteristics under full load and minimum overall thickness—yet they are reasonably priced. Imslides are manufactured at our Uxbridge works from high tensile strength aluminium alloy with a black anodised finish. The new runners weigh only 6½ lb. per pair against 18 lb. for a pair of conventional runners and are only ½" thick overall. Imslides are ready pierced with countersunk holes for fixing to certain types of rack mounting; special Imslide brackets are available which considerably extend the variety of rack mountings and give adjustment on height. Imslides are also pierced for attaching the chassis itself. Write for leaflet and details of latest light-duty Imslide



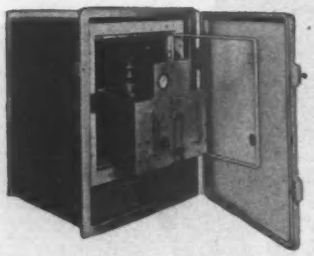
Alfred Imhof Ltd. Dept. O.10, Ashley Works, Cowley Mill Road, Uxbridge, Middx. *Uxbridge 37123*

London Showrooms: 112-116 New Oxford Street, W.C.1. *MUSeum 7878*

IMHOFS AGENTS OVERSEAS

Algeria: E.G.E.E. Paris (19)
Australia: Aladdin Industries (Pty) Ltd. Stanmore NSW
Belgium: Rogelec, Ghent
Canada: Measurement Engineering Ltd, Arnprior
Denmark: Tage Schouboe, Copenhagen N
Finland: Oy Scientx Ab, Helsinki
France: E.G.E.E. Paris (19)
Germany: Sunvic Regler GMBH Solingen-Ohligs
Holland: J. Th. van Reijsen, Delft
Italy: Stuart Culley, Milan
Mexico: Aluminio Arquitectonico S.A. Mexico D.F.
Morocco: E.G.E.E. Paris (19)
New Zealand: Imarex Ltd, Auckland C3
Norway: Birger Christensen, Oslo
Portugal: Projectos e Construçoes Lda, Lisbon
South Africa: Switchcraft (Pty) Limited, Johannesburg
Sweden: Electronlund AB, Malmo C
Switzerland: Walter Blum, Zurich 2/39
Tunisia: E.G.E.E. Paris (19)
U.S.A.: Bud Radio Inc, Cleveland 3, Ohio
British Guiana: Davsons Caribbean Agencies Ltd, Georgetown

Process Analyser



The Pye Process Analyser is an industrial version of the well-known Pye Argon Chromatograph. By utilising an argon ionisation detector instead of a katharometer or thermistors, it achieves an outstanding performance with high sensitivity and exceptional stability. Its comparatively simple and robust design results in reliability, ease of operation and low overall cost.

The instrument draws a sample from the process stream, analyses it and presents the results on a recorder. A versatile control system selects and attenuates a number of individual peaks or gives a complete chromatogram.

The equipment, which is suitable for use in hazardous locations, is completely flexible in application. Facilities which may be supplied for individual installations include dual column analysis, multi-stream analysis, column switching, flow programming and others.

PYE ....ON STREAM!

APPLICATIONS

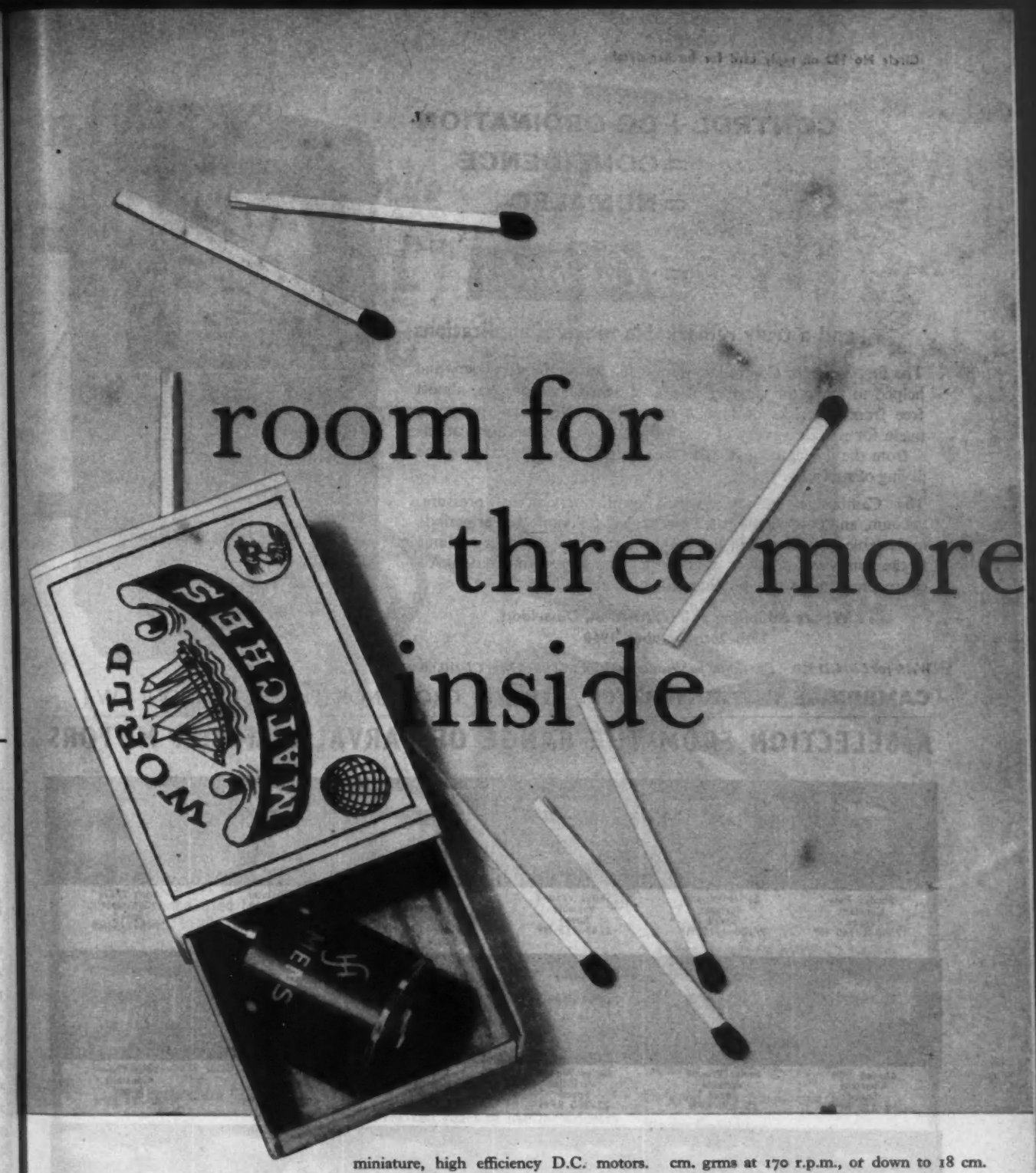
- ★ **PERCENTAGE ANALYSIS** of mixed hydrocarbons.
- ★ **TRACE IMPURITIES** in air, oxygen or industrial gases.
- ★ **MONITORING OF CRITICAL COMPONENTS** in a process stream.

PYE FEATURES

- ★ **CONTINUOUS AUTOMATIC ANALYSIS** requiring no supervision.
- ★ **ULTRA-HIGH SENSITIVITIES** for analysis in p.p.m. range.
- ★ **CONVENTIONAL SENSITIVITIES** for analysis in % range.
- ★ **VERSATILITY** in a wide range of applications.
- ★ **COMPREHENSIVE ANALYSIS FOR LESS OUTLAY** in comparison with other methods.
- ★ **AIR PURGED** for use in hazardous locations.
- ★ **BRITISH DESIGN AND BRITISH MANUFACTURE THROUGHOUT.**

W. G. PYE & CO. LTD.
Granta Works, P.O. Box 60, Cambridge, England
Telephone: CAMBRIDGE 54411 (5 lines)
Telegrams: PYE CAMBRIDGE

SCIENTIFIC PYE INSTRUMENTS



room for three more inside

Are electrical design engineers ever impressed? Do they whistle with admiration at such things as servo-components?
If they do, many we suspect, will be whistling soon at this range of Siemens-Halske miniature, high efficiency D.C. motors. Available in three sizes, the largest of which measures only two inches long by one inch in diameter, these motors have working voltages which go up to 4v D.C., but they will turn on a signal as low as 50 m.V. Available torques are up to 270 cm. grms at 170 r.p.m., or down to 18 cm. grms at 2,500 r.p.m., with an electro to mechanical efficiency of as high as 70%. The working temperature range is −35 degrees to +65 degrees C.
If you would like further information on these or our A.C. servo range, please write to:—

B & R RELAYS LIMITED

B & R RELAYS LIMITED · TEMPLE FIELDS · HARLOW · ESSEX

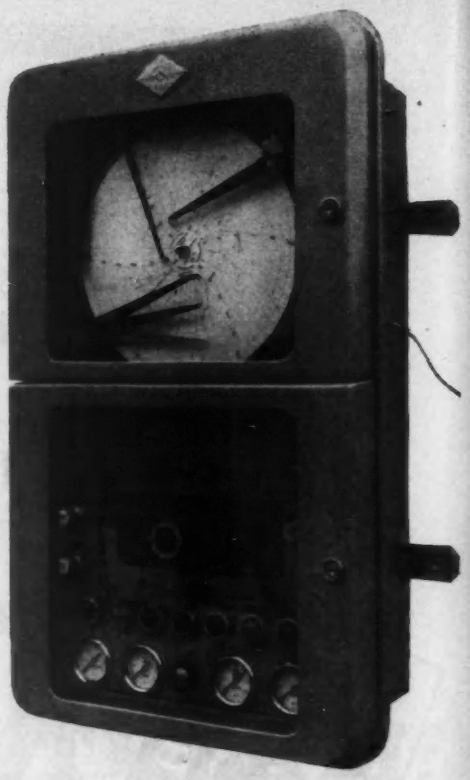
Telephone: Harlow 25231/4

Member of the Gas Purification Group

Circle No 111 on reply card for further details

Circle No 112 on reply card for further details

CONTROL + CO-ORDINATION = CONFIDENCE = NUMALEC = Cambridge



and a truly remarkable range of applications

The first Numalec Controllers were made for the food industry and helped to make the canning of peas a dependable process, almost free from the risks of human error. Now, Numalecs are being made for a wide variety of control-plus-co-ordination applications —from the dyeing of textiles to the control of humidity during the drying of roof tiles.

The Cambridge Numalec will control temperature, pressure, vacuum, and co-ordinate some mechanical functions for set periods (adjustable at will) and in the sequence required. There is no limit to the number of different stages which can be accommodated. An entire programme can be changed in three minutes.

We are exhibiting at INTERKAMA, Düsseldorf
19th–26th October, 1960

Write for List CD 310. *For future publications ask for Mailing Form CD*/10/60

CAMBRIDGE INSTRUMENT CO. LTD. 13 GROSVENOR PLACE, LONDON S.W.1

A SELECTION FROM THE RANGE OF PARVALUX F.H.P. MOTORS

Shaded Pole Constant Speed 1/300–1/140 HP	Series Wound Variable Speed 1/100–1/10 HP	Series Wound Variable Speed 1/40–1/5 HP	Capacitor Constant Speed 1/150–1/30 HP	Capacitor Constant Speed 1/40–1/5 HP	Split Phase Constant Speed 1/40–1/5 HP

Shaded Pole Constant Speed 19–330 RPM	Series Wound Variable Speed 25–800 RPM	Series Wound Variable Speed 22–800 RPM	Capacitor Constant Speed 17–680 RPM	Capacitor Constant Speed 20–700 RPM	Split Phase Constant Speed 20–700 RPM

Shaded Pole Constant Speed 1/4–18 RPM	Series Wound Variable Speed 0·5–60 RPM	Series Wound Variable Speed 0·3–60 RPM	Capacitor Constant Speed 0·3–19·5 RPM	Capacitor Constant Speed 0·2–19 RPM	Split Phase Constant Speed 0·2–19 RPM

REGD. TRADE MARK
PARVALUX
LIMITED

OUR 1960 CATALOGUE AVAILABLE ON REQUEST

PARKSTONE, POOLE, DORSET, ENG. Tel: Parkstone 5411-2 PBX Grams: Parvalux Parkstone

The more robust—
more versatile

PHOTOCELL SWITCHING EQUIPMENT

IT'S VERSATILE

Sub-unit type of construction enables it to be used for numerous applications in all types of industry.

A few examples are:

Counting
Press Feed Control
Strip Breakage Alarm
Conveyor Belt Control
Screen Protection
Level Control
Automatic Light Control
Door Control
Opacity Control

IT'S ROBUST

The use of cast aluminium cases etc. ensures maximum protection under factory conditions.

IT'S RELIABLE

Over ten years of use in industry has proved the high reliability of this equipment.

3 TYPES OF RELAY UNIT

Provide:

Simple on/off switching
Pulse Switching
Delayed Switching—release
Delayed Switching—operation
Binary Switching
Coincidence Switching

In instrumentation

Airmec *makes most things . . . better*

AIRMEC LIMITED · HIGH WYCOMBE · BUCKS Tel: High Wycombe 2501-7

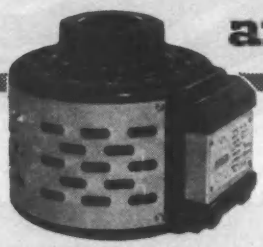
Circle No 115 on reply card for further details

- Up to 8 changeovers, 15 amp at 250V a.c.
- Light duty twin contacts can be incorporated.
- P.T.F.E. insulators on moving parts.
- Designed to withstand severe shock and vibration.
- Full tropical finish.
- **Prototypes available in 24 hours.**
- **Bulk deliveries commencing within 14 days.**

Manufacturers of the full range of
Post Office Types 3000 and 600 relays.

L. E. SIMMONDS LTD.
BYRON ROAD, HARROW, MIDDX. TEL: HARROW 7797 PBX.
TELEGRAPHIC ADDRESS: SIMRELAY, HARROW

Voltage Regulating Transformers and Line Voltage Regulators



from 250-580 VA Models 41 and 42
* *Universal fixing centres*
* *Choice of ganged or automatic models*

THE NEW MODELS 71, 72 from 1.5 to 2.5 KVA
Self-aligning brush gear
(PATENT PENDING)
* *Universal fixing centres*
* *Choice of ganged or automatic models*

BERCO

Details available from :—
THE BRITISH ELECTRIC RESISTANCE Co. Ltd.
Queensway · Enfield · Middlesex *Telephone : HOWard 2411*
Telegrams : Vitrohm, Enfield

BR 1361

Here and Now!

The I.S.I. 609 SYSTEM for Industrial Measurement and Control

The I.S.I. 609 System is a comprehensive plant measuring and control system having as its centre the well known Elliott 803 solid state digital computer.

The system is designed to work on-line with a process, but still have facilities available for calculation on a time sharing basis.

Note the following unique features

1 On-line monitoring of process variables.
2 Automatic correction for non-linearities etc.
3 Continuous data logging and alarm indication.
4 Off-line time sharing computation.
5 Solid state analogue-to-digital conversion and vice versa.
6 A wide range of input/output facilities is available.
7 Separate computer and plant operator consoles.
8 On-line automatic control.
9 Can be modified without disturbing the overall programme.

We shall be pleased to send our specialists to your works to discuss the applications of the I.S.I. 609, without any obligation.

PANELLIT LIMITED

ELSTREE WAY, BOREHAMWOOD, HERTS Telephone Elstree 2040

EA *A member of the Elliott-Automation Group*

FLAMEPROOF PRESSURE SWITCH

Designed to meet the requirements of BSS 299 for operation in hazardous atmospheres, and incorporates a stainless steel pressure element. Fully approved by the Ministry of Fuel and Power for Group 1, also 2 and 3 gases.

Pressure ranges for Type SP-1027 from 0-20 p.s.i. to maximum 300 p.s.i. Other Buxton Certified Flameproof Pressure Switches available for ranges 30" w.g. to 5,000 p.s.i. and 0-30" Hg. vacuum.

FULL DETAILS AND SPECIFICATIONS OF THE COMPLETE K.D.G. RANGE ARE READILY AVAILABLE FROM :

K.D.G. INSTRUMENTS LTD IN ASSOCIATION WITH STOW & PARTNERS LTD

MANOR ROYAL · CRAWLEY · SUSSEX TEL.: CRAWLEY 25151

LONDON SHOWROOMS, SERVICE AND SALES: 100 FLEET STREET, LONDON, E.C.4. Telephone: FLEet 5354/5

CRAWLEY KDG LONDON

"PLUG-IN" 3,000 Type Relay

NOW SUPPLIED AS FOLLOWS :

- 6 Change-overs Light Duty
- 6 Makes or 6 Breaks Heavy Duty
- 2 Change-overs Heavy Duty and 2 Change-overs Light Duty
- Transistorised to operate as low as 3 micro-amps
- A.C. Operation for : 6v. 12v. 50v. 110v. and 250v. A.C.
- Double Wound Coils
- P.T.F.E. Insulation
- Operate and Delay up to 5 Seconds.

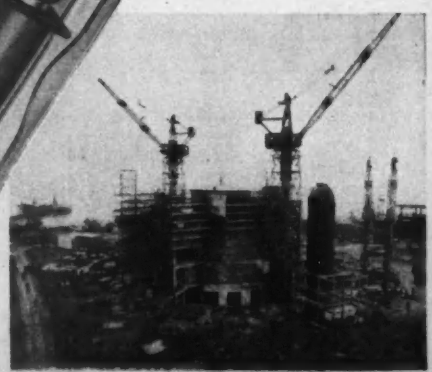
A.I.D. A.R.B.
ADMIRALTY APPROVED
3000 & 600 TYPE RELAYS

WITH TRANSPARENT DUST COVER AND PLUG-IN BASE

As supplied exclusively for

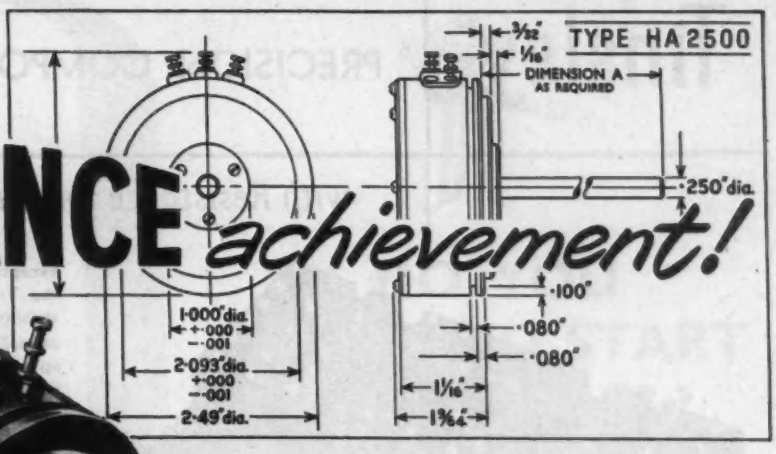
BERKELEY POWER STATION

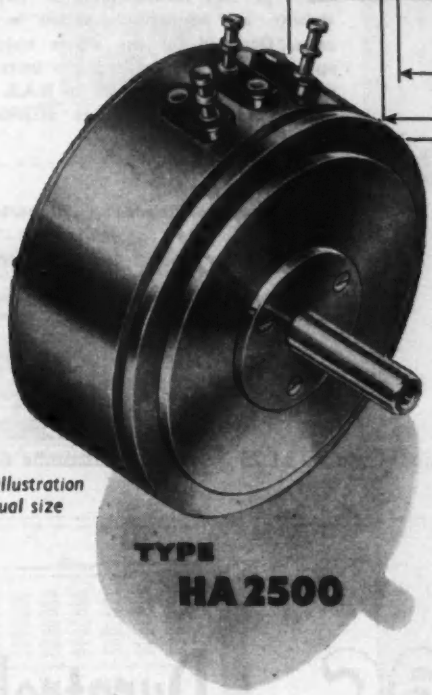
SIZE OF BASE
$2\frac{3}{8}" \times 1\frac{1}{8}" \times \frac{3}{4}"$



A.D.S. RELAYS LTD 89-97, ST. JOHN STREET, CLERKENWELL, E.C.1. Telephone : CLErkenwell 3393/4/5.

a new RELIANCE achievement!





This illustration is actual size

TYPE HA2500

HIGH LAW ACCURACY
without cam correction

In this new continuous rotation type HA 2500 Potentiometer intensive research has made possible high accuracy with much improved mechanical stability. A precision machined light alloy body, an accurately ground ball-bearing mounted spindle – a patented design that eliminates cam correction, combine to give the following advantages :—

- LOWER TORQUE
- LONGER LIFE
- REDUCED WEAR
- LOWER COST

BRIEF SPECIFICATION

Resistance range	100 to 100,000 ohms.
Law Accuracy (Absolute)	± 0.25% or ± 0.10%
(Independent law accuracy to closer limits)	
Maximum Starting Torque	1 oz/in.
Maximum Ganged Sections	Four.
Maximum Tappings	Nine.

Full technical details and dimensional drawings in Data Sheet No. 100 available on request.

●

If our standard types do not meet your particular requirements, our research and development engineers are at your service.

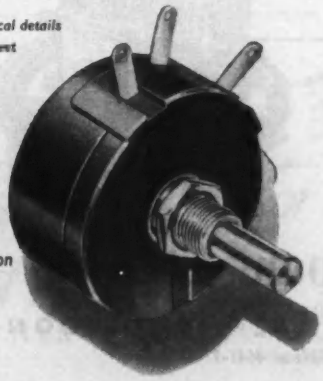
RELIANCE MANUFACTURING CO. (SOUTHWARK) LTD.
SUTHERLAND ROAD · HIGHAM HILL · WALTHAMSTOW · LONDON · E.17.
Telephone No. (and for Cables) LARkswood 1118/9

. . . **and** ANOTHER ADDITION TO THE COMPREHENSIVE RELIANCE RANGE

The **TYPE W3** (3 WATT)

This model conforms with specification DEF-5121 style RVW 7 & 8 (formerly RAC.RAD) and is a fully sealed unit with integrally constructed moulded cover. Also available in unsealed version.

Full technical details in Data Sheet No. 9



This illustration is actual size

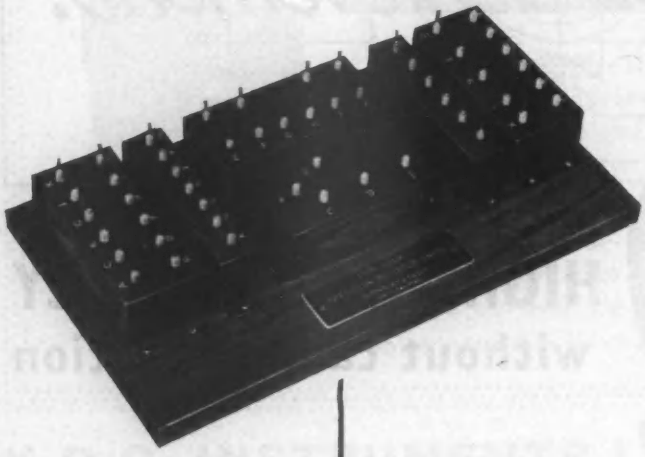
GD.40

Circle No 121 on reply card for further details

Tinsley

PRECISION COMPONENT RESISTORS

with Resistance tolerance better than 0.1%



Exceptionally compact and light in weight the Type 5206 resistor units of *very high stability* are hermetically sealed in metal cases. Designed for use where resistances up to 10 MΩ are required, the units meet the specifications laid down in R.A.E. Spec. G.1177 and satisfy the tests described in Spec. R.C.S. 11.

Rating: 500 V per MΩ
Temperature coefficient: ± 20 parts per million per °C at room temperature

Time constant: Approximately 10^{-8} seconds
Max voltage: 500 V d.c.

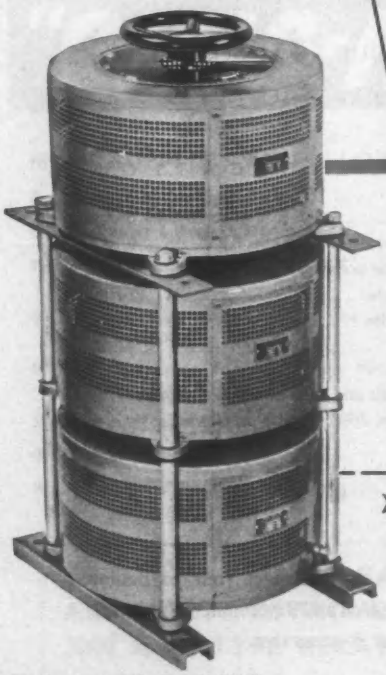
Write for full details to:

H. TINSLEY & CO. LTD. Werndee Hall, South Norwood, London, S.E.25 tel : Addiscombe 6046-8

TY 2

Variac WITH Duratrak ☆

Regd. Trademark



This 3-gang assembly, Type 50-BMG3, will control 22·5kVA, 3-phase or single-phase according to connection. Larger assemblies can be made.

THE MOST USEFUL DEVICE KNOWN FOR THE CONTROL OF AC VOLTAGE

VARIAC is the original continuously-adjustable auto-transformer, providing a smoothly variable output from zero to line voltage and above.
VARIACS are available in a very wide range of models from small units for laboratory and instrument use to large ganged assemblies for three-phase power.
VARIACS are available open or covered, as single units or ganged assemblies, for manual operation or motor-driven.

The range includes portable, metalclad and oil-immersed models, dual-output types, high-frequency types and many 'specials'. *Write for complete information.*

☆ **Duratrak?** Duratrak (Regd. Trademark) —a patented* feature exclusive to Variac—is a special plated contact surface giving longer life, increased overload and surge capacity and maximum economy in maintenance. Duratrak is now standard on all models except Series 50.

**U.K. Pat. No. 693406*

ONLY VARIAC HAS DURATRAK

This small Variac, Type V-5HMTF, provides an output of 0-270 V, 2 A, from 240 V 50 c/s mains. A still smaller model, Type V-3H is rated at 1 A.

Claude Lyons Ltd.

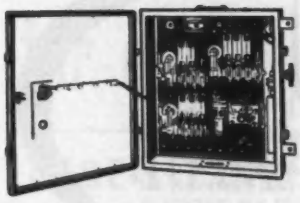
VALLEY WORKS · HODDESDON · HERTS · TEL: HODDESDON 4541-6

and 76 Old Hall Street · Liverpool 3 · Tel: CENtral 4641-2

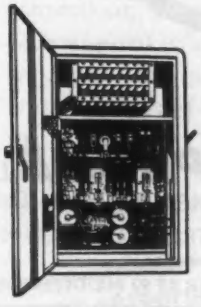
CL 59/22

Circle No 124 on reply card for further details

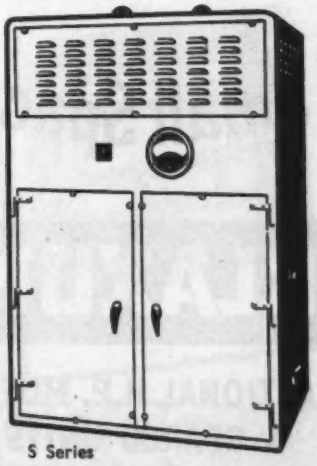
TF Series



TS Series



SR Series



S Series

DO YOU WANT TO START SOMETHING?

... to start and control, correctly and safely, an electric motor in any type of plant, from a sweet-wrapping machine to a steel-rolling mill —all with relentless efficiency—then ...

PICK ON DEWHURST!

- ★ Range (a.c. or d.c.)—¼ to 800 h.p.
- ★ For operation in any climate—from the tropics to the poles.
- ★ All methods of starting and control—local or remote.
- ★ Assembled from standard components, keeping prices competitive and giving the delivery you require.
- ★ Optional features include reversing duty, varying forms of motor protection, interlocked isolating switch etc.
- ★ Consult our Technical Advisory Service for assistance on your control gear problems.

DUPAR *for dependability*

DEWHURST
& PARTNER LIMITED

INVERNESS WORKS · HOUNSLOW · MIDDLESEX

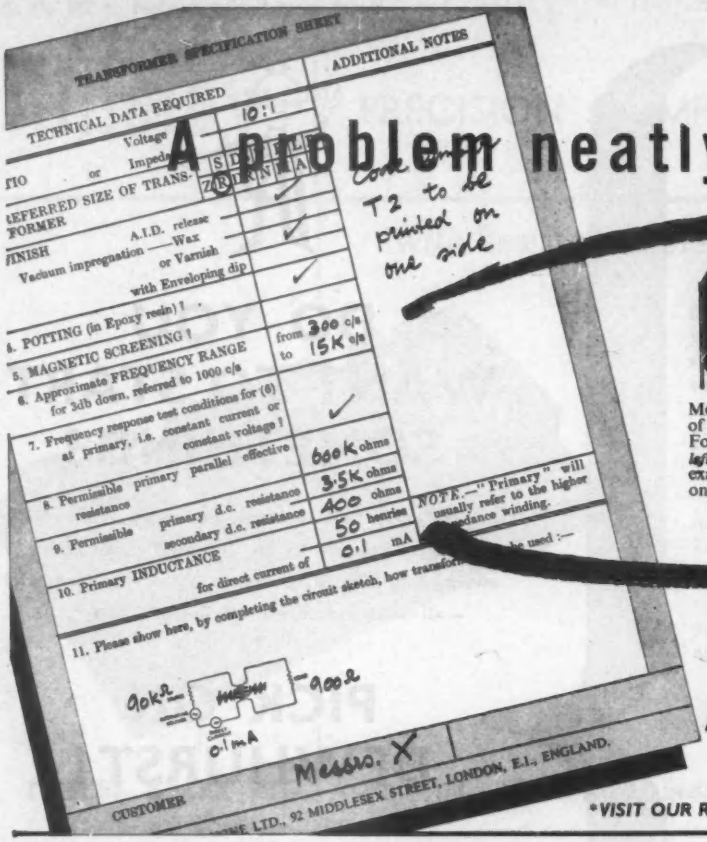
Telephone: HOUnslow 7791 (12 lines) Telegrams: DEWHURST HOUNSLOW

Field Offices at:—
BIRMINGHAM · GLASGOW · GLOUCESTER · LEEDS · MANCHESTER · NEWCASTLE · NOTTINGHAM

DP/G1

Circle No 124 on reply card for further details

A problem neatly solved . . .


TRANSFORMER SPECIFICATION SHEET
TECHNICAL DATA REQUIRED
ADDITIONAL NOTES
10:1
Voltage
or Impedance
SCREENED
PRIMARY
SECONDARY
Code T2 to be printed on one side
REFERRED SIZE OF TRANSFORMER
FINISH
A.I.D. release Wax or Varnish
Vacuum impregnation with Enveloping dip
6. POTTING (in Epoxy resin) ?
5. MAGNETIC SCREENING ?
6. Approximate FREQUENCY RANGE for 3db down, referred to 1000 c/s
from 300 c/s to 15K c/s
7. Frequency response test conditions for (6) at primary, i.e. constant current or constant voltage ?
8. Permissible primary parallel effective resistance
600K ohms
9. Permissible primary d.c. resistance
3·5K ohms
secondary d.c. resistance
400 ohms
10. Primary INDUCTANCE
50 henries
for direct current of
0·1 mA
NOTE.—"Primary" will usually refer to the higher impedance winding.
11. Please show here, by completing the circuit sketch, how transformer is to be used :—
90kΩ
900Ω
0·1 mA
Messrs. X
CUSTOMER
92 MIDDLESEX STREET, LONDON, E.1., ENGLAND.

Messrs. X. wanted this special type of transformer . . . with the help of a Fortiphone specification sheet *(on the left)*, and our vast experience, his exact requirement was provided in only a few days.

Enquiries to:

FORTIPHONE LTD
TRANSFORMER DIVISION, (Dept. 3)
92 MIDDLESEX STREET, LONDON E.1
Bishopsgate 0871
**VISIT OUR RETAIL SALES COUNTER AT 92 MIDDLESEX STREET*

For POWER in Small Spaces

-specify **KLAXON**

FRACTIONAL H.P. MOTORS & GEARED UNITS

KLAXON fractional horse-power Motors and Geared Units provide adequate motive power in those difficult situations where space is strictly limited. With an infinite variation of torque, from zero to 2,500 lbs./ins., and from one two-thousandth up to one horse-power in size, these fractionals and geared units are the obvious choice in the many situations where dependability is of first importance.

Full technical information on request.

The KLAXON Range includes:—

Fractional Horse-power Motors—A.C./D.C. and D.C. Series. **Windings**—D.C. Shunt and Compound Windings. **A.C. Induction Motors**—1, 2 and 3-Phase. **Flameproof Enclosures, Synchronous Motors, Geared Motor Units**—0-1,400 R.P.M. Torque up to 2,500 pounds/inches. **Single Worm, Double Worm, Worm and Multispur, Spur.**

KLAXON LTD., WARWICK ROAD, TYSELEY, BIRMINGHAM 11

LONDON SALES OFFICE: 189-191 DRUMMOND STREET, N.W.1. Tel: EUSton 4102 and 4143. *One of the Windsor Group of Companies*

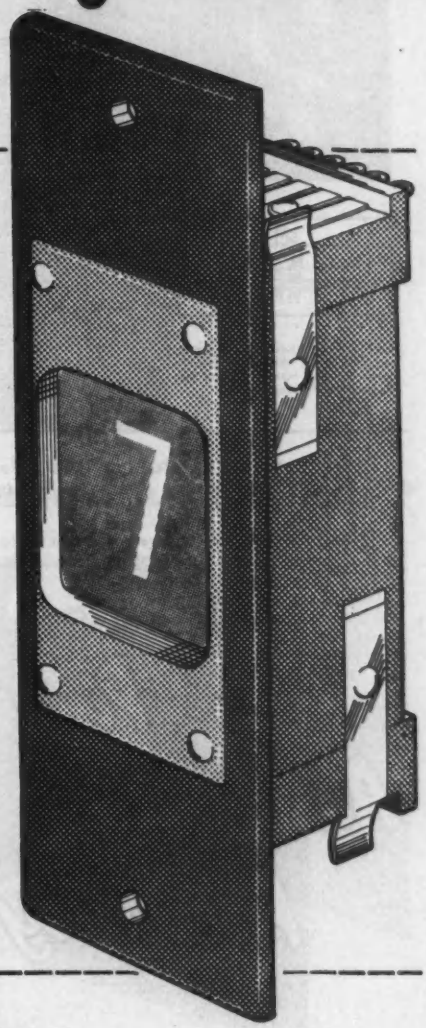
A3

Thorn read-out systems

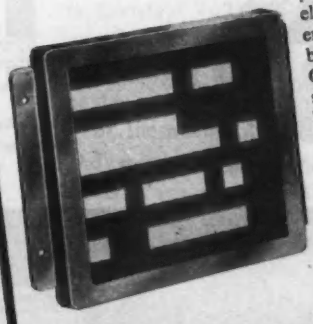
for digital computors

EDGE-LIT INDICATOR

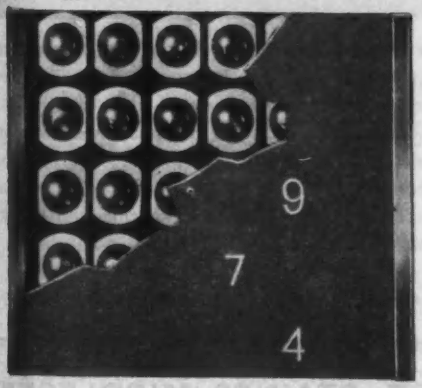
Simple unit structure, easy relamping, robust in-line solder tag connections, 12 circuits. Display includes numerals 0—9 with decimal point (which may be illuminated with two lamps) or with plus and minus signs. Thorn Midget Panel Lamps, in voltage ratings of 28, 12, 6 or 4 (AC-DC) are used to illuminate the characters. Can be supplied separately or with ancillary relay equipment for complete readout system. Overall dimensions $1\frac{1}{8}$″ deep x $4\frac{3}{4}$″ long x $1\frac{3}{8}$″ wide.



ELECTROLUMINESCENT INDICATOR BLOCK

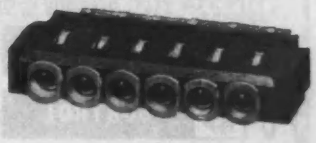


The device is a slim glass plate with an array of 100 electroluminescent spots energised from a printed circuit bonded to the rear face. Characters can be built up by suitable combinations of connections. The current consumed by each illuminated spot is a fraction of a milli-amp, the voltage required being of the order of 300 volts with a frequency range of up to 400 c.p.s. It is available as a separate component or as part of a complete read-out system. Overall dimensions:— 3.500″ x 3.000″ x .265″.



MULTIPLE LAMPHOLDER

When mounted in banks, the Thorn Multiple Lampholder (below) provides a clear legible read-out through variation in the pattern of illuminated Midget Panel Lamps. The bank of Lampholders can be overlayed with a sheet of "Plasteck" on which the desired characters are engraved—each character lining up with one filament. The cut-away illustration (left) shows the read-out system provided by this arrangement. Overall dimensions:—0.430″ x 2.475″ x 1.250″ inc. terminals.



Thorn THORN ELECTRICAL INDUSTRIES LIMITED SPECIAL PRODUCTS DIVISION (INCORPORATING COMPONENTS & CONNECTORS) GREAT CAMBRIDGE ROAD, ENFIELD, MIDDLESEX *Tel:* ENField 5353

Circle No 127 on reply card for further details

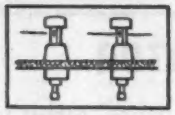
LS products for the Electronics Industry

TRANSISTOR CLIPS
in Beryllium Copper

(Patent and Type Approval applied for)

Of compact design, and taking up no more room than the Transistor itself, these Clips, manufactured from Beryllium Copper and formed so as to assist heat dissipation, are designed to suit cylindrical Transistors such as the Mullard OC.72 for fixing horizontally to printed circuit boards.

Top illustration shows the clip greatly enlarged whilst the lower picture shows the clip actual size and also the method of fixing.



Pressure on the terminal cap opens the transverse hole and allows the wire or pin to be inserted. Release pressure and wire or pin is firmly held in position.

SPRING LOADED WIRING TERMINAL

Designed for mounting on panels up to $\frac{1}{8}$" thick, the terminal accepts wire ends or pins up to $\frac{1}{8}$" diameter and provides a quick and simple connection, secure and proof against vibration. Terminals are available from stock with Black or Red Thermo-plastic fittings or other colours to order.

Ratings :—Current 5 amp. Test Voltage 1000 V., with contact resistance. (Patent and Type Approval applied for).

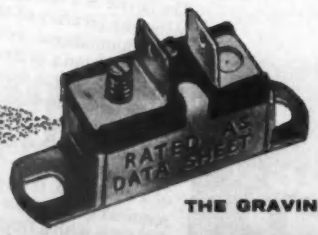
for Reliability . .

LEAVE IT TO **Lewis** OF REDDITCH
SPRINGS, PRESSWORK AND WIRE FORMS TO FINE LIMITS

THE LEWIS SPRING CO. LTD., Resilient Works, Redditch.
London Office: 122 High Holborn, W.C.1.

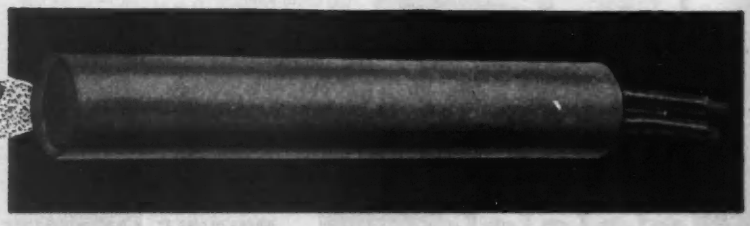
Send 2/6 P.O. for our 40 page booklet on spring design with full technical data. It is an invaluable reference for your design department.

Pin-point Automatic Accuracy



THE GRAVINETTE

Write for Catalogue G. 100 Temperature Control Switches



THE GRAVINETTE

A miniature precision unit for Surface Mounting, to provide for optimum temperature control on applications where space is at a premium. The Gravinette is an adjustable unit and is offered in four versions :—

Type TCS 3150, normally closed, range—70°C to 100°C,
Type TCS 3151, normally open, range—70°C to 100°C,
Type TCS 3250, normally closed, range 40°C to 250°C,
Type TCS 3251, normally open, range 40°C to 250°C.

Normal rating 1 amp. on 250v A.C., and 2 amps on 28v D.C.

CARTRIDGE TYPE SERIES 1000, TENSION OPERATED

These precision temperature control switches are designed primarily for use in heater blocks, heated plates and similar applications where excessive moisture or vapour is not present. Possessing the desirable features of the ideal thermostat, the Graviner Temperature Control Switch is of convenient size and shape, adjustable and resistant to vibration and shock, and easy to install.

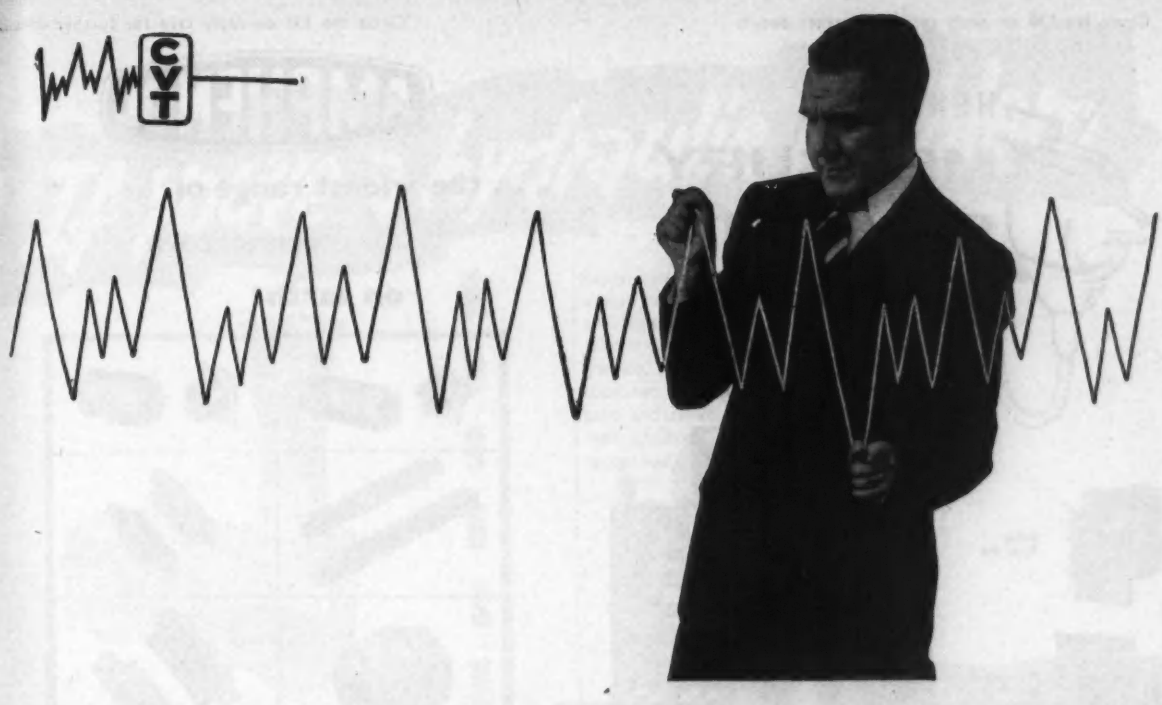
Current Rating 5 amps 250 v. A.C. for standard types.

T TEMPERATURE
C CONTROL
S SWITCHES

For further details of our complete range write or telephone

GRAVINER, 10 CHURCH ST., STAINES, MIDDLESEX
Telephone: Staines 51217

Specialists in Airborne and Industrial Fire and Explosion Protection, Nuclear Development and Production Engineering



Why struggle with Mains Voltage Fluctuation?

If you have any problems involving a.c. voltage regulation, the solution is to call in 'Advance'—the Constant Voltage Transformer specialists. Investigation of your problem may prove that a standard type 'Volstat' will meet the case; or maybe, a special design is called for. In either event, the wealth of experience gained by 'Advance' over many years in probing every aspect of mains stabilization provides the surest, quickest, and certainly the most economical, solution to your difficulties.

VOLSTAT

CONSTANT VOLTAGE TRANSFORMERS

INTERKAMA

STAND No. B2025/6/D

'VOLTAGE STABILIZATION'

This 'Advance' Booklet gives authoritative information on 'Advance' Constant Voltage Transformers, and the service available to deal with your particular voltage fluctuation problems. Send for a copy.

POST THIS COUPON TODAY

Advance

To ADVANCE COMPONENTS LIMITED, ROEBUCK ROAD, HAINAULT, ILFORD, ESSEX

Please send me a copy of your booklet "Voltage Stabilization" by 'Advance'

NAME .....

POSITION .....

COMPANY .....

ADDRESS .....

.....

G 84

Advance COMPONENTS LIMITED

MAINS STABILIZATION DIVISION

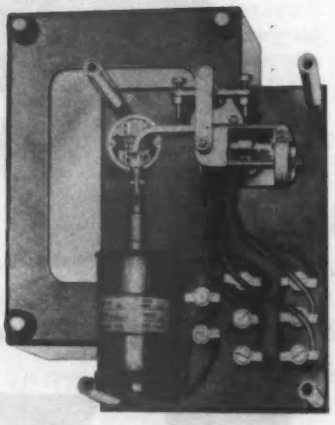
ROEBUCK ROAD • HAINAULT • ILFORD • ESSEX • TELEPHONE: HAINAULT 4444

IT/GD84

Circle No 130 on reply card for further details

HENDREY

MERCURY SWITCH Relays



Relay Type MS

Mercury Switch Contactor Type ERS

Relay Type PS

Relay Type DSS

Relay Type SSVT

Mains Failure Contactor

Type SS

The type SS relay is solenoid operated and is one of the most popular mercury switch relays because of its reliability and the large number of contact arrangements possible. The movement is counterbalanced and gravity controlled, automatically resetting when coil is de-energised. The relay is mounted on a polished black bakelite base with clamp type front connecting terminals as standard.

For full details and specifications ask for the appropriate Catalogue Sheet.

Hendrey Relays

HENDREY RELAYS LIMITED · BATH ROAD · SLOUGH · BUCKS

Telephone: Burnham 609/611

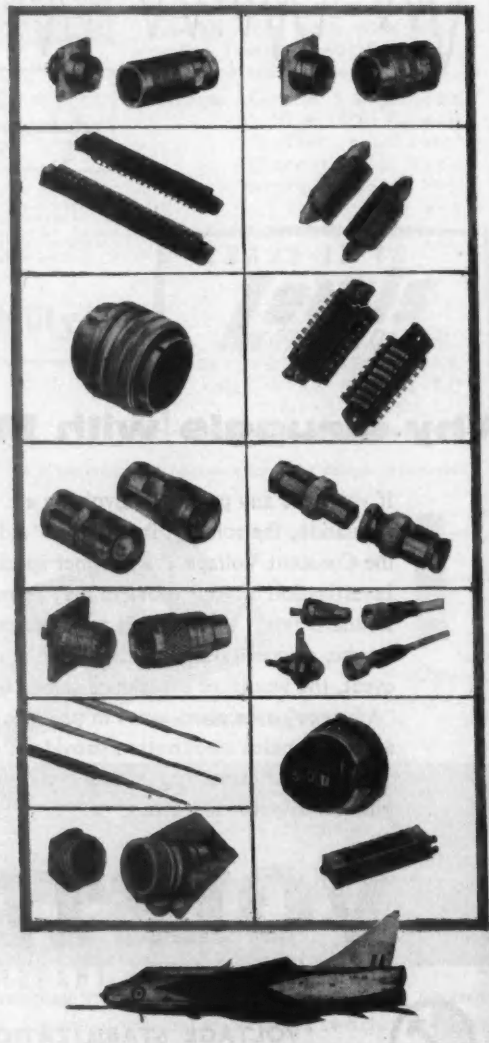
MANUFACTURING ELECTRICAL ENGINEERS
CONTROL AND LABORATORY APPARATUS

On Admiralty, Principal Ministries and Post Office Lists
A.I.D. and A.R.B. Approved

Circle No 131 on reply card for further details

AMPHENOL

. . . the widest range of connectors on earth!



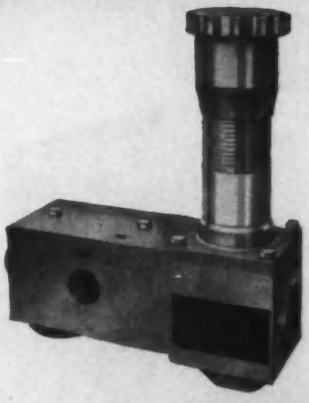
The ARC 52 Equipment installed in the "Lightning" (photo reproduced by courtesy of the English Electric Company Ltd.), the Vickers-Armstrong "Scimitar" and other military aircraft incorporates Amphenol 165 Series Connectors.

In industrial electronics, in research, in the Navy, Army and Royal Air Force, in the air, under the sea, in computers, guided weapons and automation, Amphenol Connectors fulfil a significant function as a vital link in equipment where growing complexity must be matched by increased reliability. Each connector in the vast Amphenol Range of types, arrangements and applications has its own special features. But none is more important, or more widely recognised, than the quality of complete reliability inherent in every product bearing the Amphenol Trade Mark. **Get in touch with us today and ask for detailed catalogue information.**

AMPHENOL (GREAT BRITAIN) LIMITED,
Victoria Road, Burgess Hill, Sussex. Tel: Burgess Hill 85616

AMPHENOL-BORG ELECTRONICS CORP., CHICAGO, U.S.A.
AMPHENOL CANADA LTD., TORONTO 9, ONTARIO.

If you've a hydraulic problem



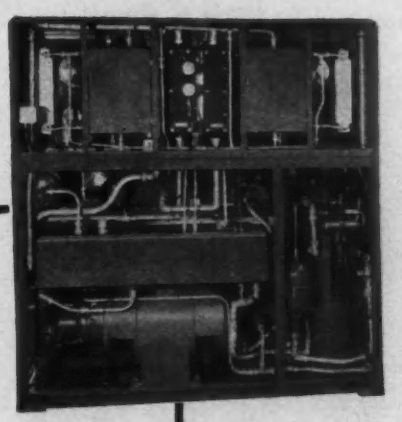
Experienced engineers at HML are always ready to get to grips with problems arising from the design requirements of modern hydraulic systems. You'll find HML Ministry approved units and components used and relied upon wherever high standards of performance are recognised.

HML VARIABLE PRESSURE REDUCER VALVE

The only pressure reducing valve on the market today that will maintain set reduced pressure under varying pressure and flow conditions.
Pressure range 0–5000 p.s.i.
Flow range 0–10 g.p.m.

... bring it to HML

All types of special hydraulic test equipment built to users' own requirements. The unit shown was supplied to a large aircraft company.



HML EQUIPMENT INCLUDES:

- Pulsometer Pump Test Unit
- High-pressure Filters
- Hydraulic Propeller Test Benches
- Autostatic Hydraulic Power Pack
- Universal Hydraulic Tyre Remover
- Aircraft Pump and Hydraulic Motor Test Rig
- Air Bleed Turbines for Starting and Pressure Testing
- Valves
- Brake Test Unit
- Tensioning Test Unit
- High-speed Gear Boxes
- High-pressure Accumulators
- Hydrostatic Rig (Single and Double Acting)
- Universal Hydraulic Test Rigs Mk. II, Mk. III and Mk. IV (Diesel or Electric Powered)

HML (ENGINEERING) LTD. *AIRCRAFT DIVISION*

Head Office: 466-490 Edgware Road, London, W.2.
Harpers Yard, St. John's Road, Isleworth, Middlesex. Tel.: ISLeworth 3011

Circle No 132 on reply card for further details

. . . with

BIG

advantages in electronics and all very small wiring

- Cuts wiring time by 52%.
- Combines high-speed fixing with simplicity and complete security.
- Brings a new versatility, compactness and neatness to your wiring.
- Completely insulated and suitable for all climates.
- Electrical and mechanical security in all conditions.

The Cradleclip System has been

★ Proved in wiring installations throughout the world.

★ Wiring modifications are quickly and easily carried out.

The Miniature Cradleclip system revolutionises small wiring installation.

Designed specially for Electronics and all very small wiring with the object of considerably reducing wiring time, and is absolutely foolproof in application and completely safe and permanent in operation even in extreme climatic conditions.

Miniature Cradleclip will accommodate up to either three $\frac{1}{16}$" cables, or 20 runs of $\frac{1}{16}$" DIA. covered wire, and has all the "one two and it's done" slickness of its big brother, the now firmly established CRADLECLIP system from which it has been developed.

miniature
Insuloid cradleclip

Twice as good . . . twice as quick when you wire with CRADLECLIP

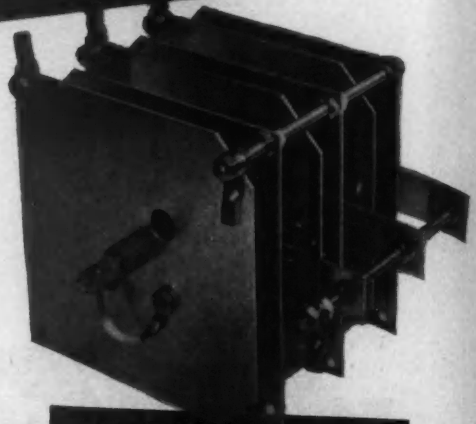
Send for fully descriptive literature on the Insuloid Miniature Cradleclip Wiring System now.

INSULOID MANUFACTURING CO. LTD.

SHARSTON WORKS, LEASTON AVENUE, WYTHENSHAWE, MANCHESTER. Tel.: WYT 2842 & 3163

Semiconductor power rectifiers

HIGH QUALITY



5·6 KILOWATTS

for under £19!

This bridge, which provides 30 amps at 188 volts, costs £18.13.0d. and is an example of the attractively priced rectifiers in our range.

We can supply 10 amp and 50 amp cells with maximum p.i.v. up to 400 volts ex stock, and stack assemblies of them in all the usual connections. The small losses in these modern devices permit rectification efficiencies well in excess of 99%. May we send you details and prices?

J. STONE & CO. (DEPTFORD) LTD.

ARKLOW ROAD LONDON S.E.14.

ESTABLISHED 1831

STONE PLATT GROUP

Full information on request from

SEMICONDUCTOR DIVISION

LOCATION 14 GATWICK ROAD CRAWLEY TEL: 25251

SERVICE DE RENSEIGNEMENTS POUR NOS LECTEURS

Il est souvent difficile au client publicitaire d'indiquer dans un espace restreint tous les détails de ses produits. Dans le cas où vous désireriez de plus amples renseignements à ce sujet, veuillez peindre le numéro approprié sur la carte ci-contre et envoyer cette dernière à CONTROL

AUSKUNFTSDIENST FÜR LESER

Es ist oft schwierig für Inserenten alle technischen Einzelheiten über ihre Produkte in einem begrenzten Platz zu bringen. Sollten Sie noch weitere Auskünfte wünschen, streichen Sie einfach die bestimmten Nummern auf der nebenstehenden Karte an, und senden Sie sie an CONTROL

SERVIZIO D'INFORMAZIONI PER I NOSTRI LETTORI

E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desiderasse ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a CONTROL

SERVICIO DE INFORMACIÓN PARA EL LECTOR

Se hace a menudo difícil para los anunciantes dar en un espacio limitado todos los detalles técnicos sobre sus productos. Si desea ulterior información, marque los números apropiados en la tarjeta opuesta y mándela a CONTROL

Информация для читателей

Часто бывает трудно рекламирующим лицам давать все технические подробности своей продукции в рекламе. Если Вам понадобятся дополнительные сведения, то просто отметьте соответствующие номера на почтовой открытке на противоположной стороне и отправьте в CONTROL

讀者詢問服務

在廣告上以有限的地方來解釋一般專門技術，是它們的缺點，如果是有更詳細的圖表或者加進一些詳細的特點說明可能的生物，那一張下來附加下有疑問的項目，用筆勾一下寄給予免工程范即可。

読者サービス

廣告紙面の関係上製品の技術的細目は掲載しきれませんので詳しくは貴社のカードの適当なナンバーに印をつけて送るか完成面してすればお答へします。

CONTROL READER INFORMATION SERVICE October 1960

ADVERTISEMENTS

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130
131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170
171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190
191	192	193	194	195	196	197	198	199	200

NEW PRODUCTS & TECHNICAL LITERATURE

511	512	513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528	529	530
531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570

BOOKS

701	702	703	704	705	706	707	708	709	710

If you would like further information about any advertisement or editorial item, simply circle the appropriate numbers on this card and mail to CONTROL.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

CONTROL READER INFORMATION SERVICE October 1960

ADVERTISEMENTS

1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
31 32 33 34 35 36 37 38 39 40
41 42 43 44 45 46 47 48 49 50
51 52 53 54 55 56 57 58 59 60
61 62 63 64 65 66 67 68 69 70
71 72 73 74 75 76 77 78 79 80
81 82 83 84 85 86 87 88 89 90
91 92 93 94 95 96 97 98 99 100
101 102 103 104 105 106 107 108 109 110
111 112 113 114 115 116 117 118 119 120
121 122 123 124 125 126 127 128 129 130
131 132 133 134 135 136 137 138 139 140
141 142 143 144 145 146 147 148 149 150
151 152 153 154 155 156 157 158 159 160
161 162 163 164 165 166 167 168 169 170
171 172 173 174 175 176 177 178 179 180
181 182 183 184 185 186 187 188 189 190
191 192 193 194 195 196 197 198 199 200

NEW PRODUCTS & TECHNICAL LITERATURE

511 512 513 514 515 516 517 518 519 520
521 522 523 524 525 526 527 528 529 530
531 532 533 534 535 536 537 538 539 540
541 542 543 544 545 546 547 548 549 550
551 552 553 554 555 556 557 558 559 560
561 562 563 564 565 566 567 568 569 570

BOOKS

701 702 703 704 705 706 707 708 709 710

If you would like further information about any advertisement or editorial item, simply circle the appropriate numbers on this card and mail to CONTROL.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

CONTROL READER INFORMATION SERVICE October 1960

ADVERTISEMENTS

1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
31 32 33 34 35 36 37 38 39 40
41 42 43 44 45 46 47 48 49 50
51 52 53 54 55 56 57 58 59 60
61 62 63 64 65 66 67 68 69 70
71 72 73 74 75 76 77 78 79 80
81 82 83 84 85 86 87 88 89 90
91 92 93 94 95 96 97 98 99 100
101 102 103 104 105 106 107 108 109 110
111 112 113 114 115 116 117 118 119 120
121 122 123 124 125 126 127 128 129 130
131 132 133 134 135 136 137 138 139 140
141 142 143 144 145 146 147 148 149 150
151 152 153 154 155 156 157 158 159 160
161 162 163 164 165 166 167 168 169 170
171 172 173 174 175 176 177 178 179 180
181 182 183 184 185 186 187 188 189 190
191 192 193 194 195 196 197 198 199 200

NEW PRODUCTS & TECHNICAL LITERATURE

511 512 513 514 515 516 517 518 519 520
521 522 523 524 525 526 527 528 529 530
531 532 533 534 535 536 537 538 539 540
541 542 543 544 545 546 547 548 549 550
551 552 553 554 555 556 557 558 559 560
561 562 563 564 565 566 567 568 569 570

BOOKS

701 702 703 704 705 706 707 708 709 710

If you would like further information about any advertisement or editorial item, simply circle the appropriate numbers on this card and mail to CONTROL.

NAME

NAME OF BUSINESS

ADDRESS

POSITION HELD

NATURE OF BUSINESS

Postage will be paid by Control

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

CONTROL
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

Postage will be paid by Control

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

CONTROL
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

Postage will be paid by Control

No Postage stamp necessary if posted in Great Britain or Northern Ireland

Business Reply Folder Licence WD 1823

CONTROL
Rowse Muir Publications Ltd,
The Rowse Muir Building,
77–79 Charlotte Street,
London, W1
England

Thousands of firms have *already* proved that the 'TRANSITROL'

Regd.

COMBINES MAXIMUM RELIABILITY WITH LONG-LIFE SERVICE

TYPE 990: Two-position (on/off) Controller
TYPE 991: Anticipatory Controller
TYPE 992: Proportioning (stepless) Controller
TYPE 993: Three-position Controller
TYPE 994: Programme Controller
TYPE 995: Proportioning (plus reset) Controller

from **£35 · 10s**

DELIVERED

Since 1956, *when Ether Ltd. invented the transistorised indicating temperature-controller, thousands of these remarkable, direct-deflection instruments have been supplied to the STEEL, PLASTICS, RUBBER, CHEMICAL and PETROLEUM industries at home and overseas.*

Ether Transitrol Controllers, essentially simple in design, are accurate, reliable and surprisingly inexpensive. They employ no thermionic valves and they require no warming-up time. Ether Transitrol Controllers were the first in the field; they are still the finest.

ENQUIRIES, SALES & SERVICE:
Tyburn Road, Erdington, Birmingham, 24
East 0276-8

Caxton Way, Stevenage, Herts.
Stevenage 2110-7

Representatives throughout the U.K.
Agents in all principal countries

ETHER
LIMITED

Circle No 136 on reply card for further details

FOR THE PLANT YOU MAKE

Do you specify BAILEY'S pressure regulators?

RELIABILITY... LONG SERVICE... EASE OF MAINTENANCE

Leading design engineers in industries of all types have learned from experience that they can depend on Bailey's pressure regulators to give greater reliability, ease of maintenance and long working life in industrial equipments of all descriptions. By incorporating Bailey's valves in the plant you are designing or producing you will give your products an additional selling advantage.

BAILEY'S UNIQUE SERVICE

In addition to producing a wide range of pressure regulators for controlling steam, air, water, gases and oil, Bailey's offer a complete advisory service on medium and low pressure applications. They will gladly advise on any installation and can supply most of the ancillary components you will require.

PLEASE WRITE FOR FURTHER DETAILS

Bailey's REGD.

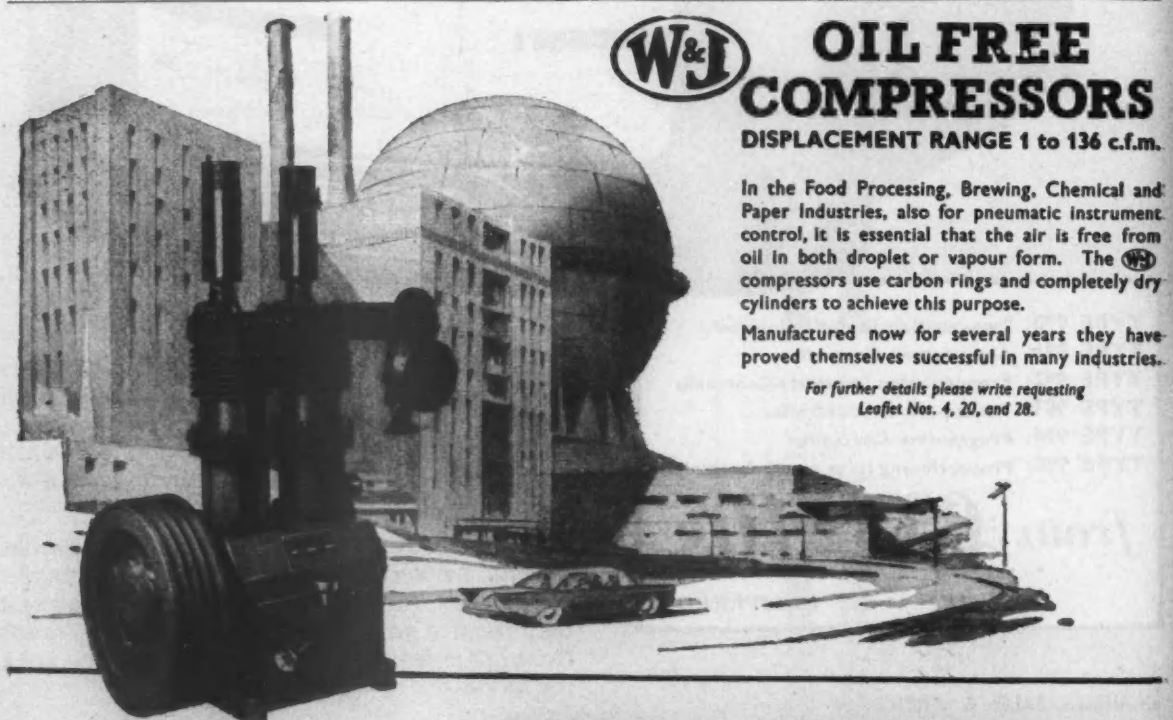
SIR W. H. BAILEY & COMPANY LTD · PATRICROFT · MANCHESTER · ENGLAND

Telephone: Eccles 3487/8/9 Grams: Beacon, Telex, Eccles

LONDON OFFICE: Selinas Lane, Dagenham, Essex Telephone: Dominion 2277/8/9

PRESSURE REGULATORS · PARALLEL SLIDE VALVES · SLUICE VALVES · TEST PUMPS

TGA RV13A.



W&J

OIL FREE COMPRESSORS

DISPLACEMENT RANGE 1 to 136 c.f.m.

In the Food Processing, Brewing, Chemical and Paper Industries, also for pneumatic instrument control, it is essential that the air is free from oil in both droplet or vapour form. The W&J compressors use carbon rings and completely dry cylinders to achieve this purpose.

Manufactured now for several years they have proved themselves successful in many industries.

For further details please write requesting Leaflet Nos. 4, 20, and 28.

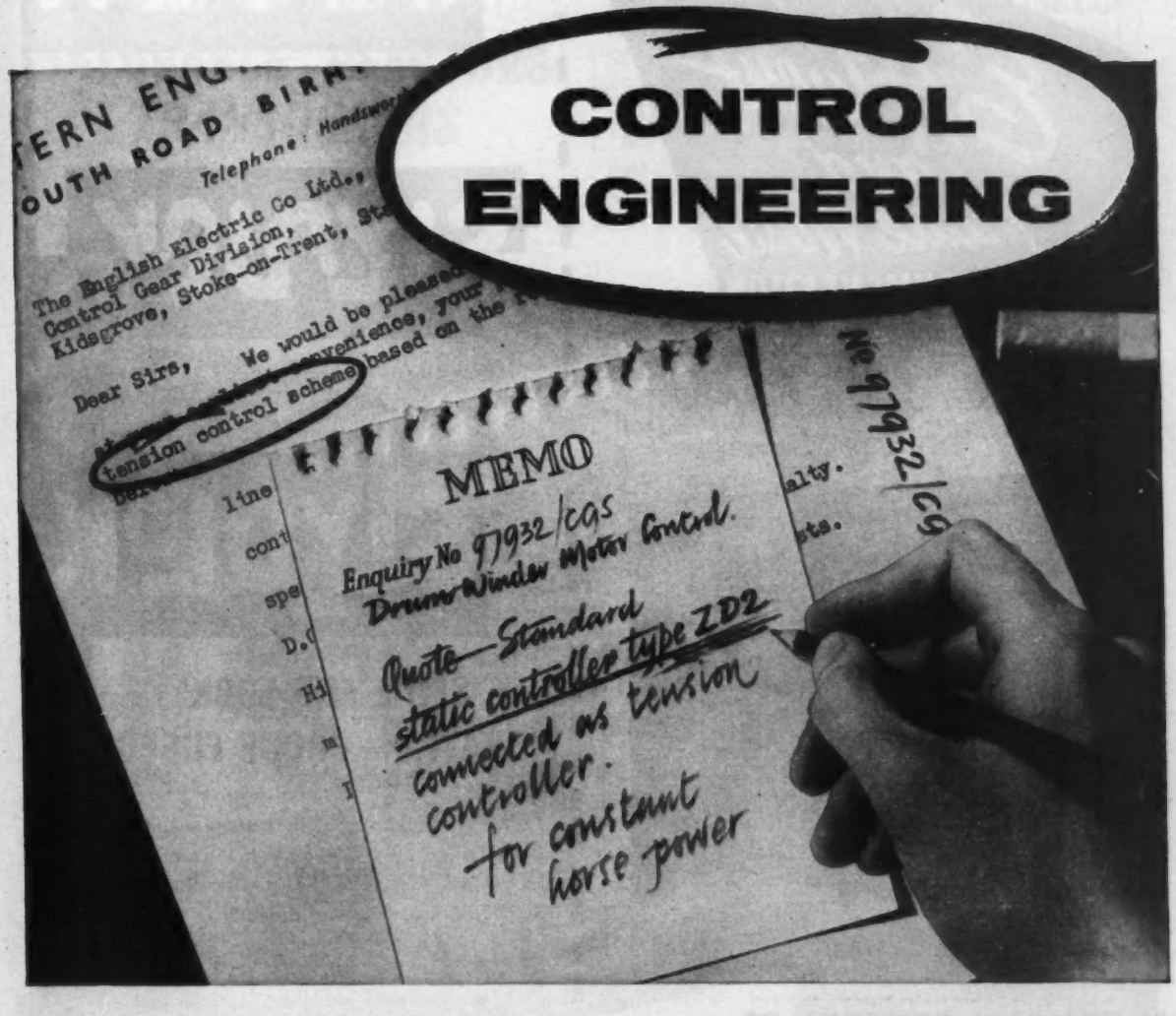
Illustrated is the twin cylinder model having a free air delivery of 50 c.f.m.

WILLIAMS & JAMES ENGINEERS LIMITED

GLOUCESTER · ENGLAND

TELEPHONE GLOUCESTER 24021-2-3 TELEGRAMS & CABLES COMPRESSOR GLOUCESTER

'ENGLISH ELECTRIC' standardised control schemes—the result of control engineering experience in many industries—can be readily applied to particular requirements. The use of these basic designs keeps time and cost to a minimum, even on special schemes.



THE RANGE OF STANDARD VARIABLE SPEED D.C. DRIVES

type ZD2 (A.C. Supplies/Static Controller/D.C. Motor), extends from ¼ horse power to 100 horse power. These drives have a wide speed range and close regulation with inherent field failure protection and current limit protection.

For further details send for leaflet ES/203

'ENGLISH ELECTRIC'
control gear

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2
Control Gear Division, Kidsgrove, Stoke-on-Trent, Staffs. Telephone: Kidsgrove 2141/3
CG.2 WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

Circle No 139 on reply card for further details

Lock INSTRUMENTATION

NUCLEAR CHEMICAL ELECTRONIC

Effluent and Trade Waste INSTRUMENTATION BY Lock

AUTOMATIC CONTROL OF

pH NEUTRALISATION OF EFFLUENT

RAPID CONTINUOUS DETOXICATION OF TRADE WASTE CONTAINING CYANIDE AND CHROMATE

A. M. LOCK & CO LTD

79 UNION STREET, OLDHAM, LANCS.

Telephone: MAin 6744

CW6804

Circle No 140 on reply card for further details

SLYDLOK

SLYDLOK

SLYDLOK

THE 'SLIDE AND LOCK' VIBRATION-PROOF FUSEGEAR

As with the name, so with the fuse, slide the top into position and there you have the anti-vibration lock which has been the feature distinguishing SLYDLOK fuses the world over.

- *Moulded in black plastic.*
- *Rewireable and H.R.C. types for 250V. and 440V. use.*
- *Patterns for surface and inset mounting, and a quite incredible variety of methods for connecting base cables.*

In case you haven't heard, the latest "H" units are also offered complete with inbuilt neon indicator lamps.

These you must see!!

They are all in the book, the Slydlok Fuse Catalogue, send for your copy now.

EDWARD WILCOX

AND COMPANY LIMITED

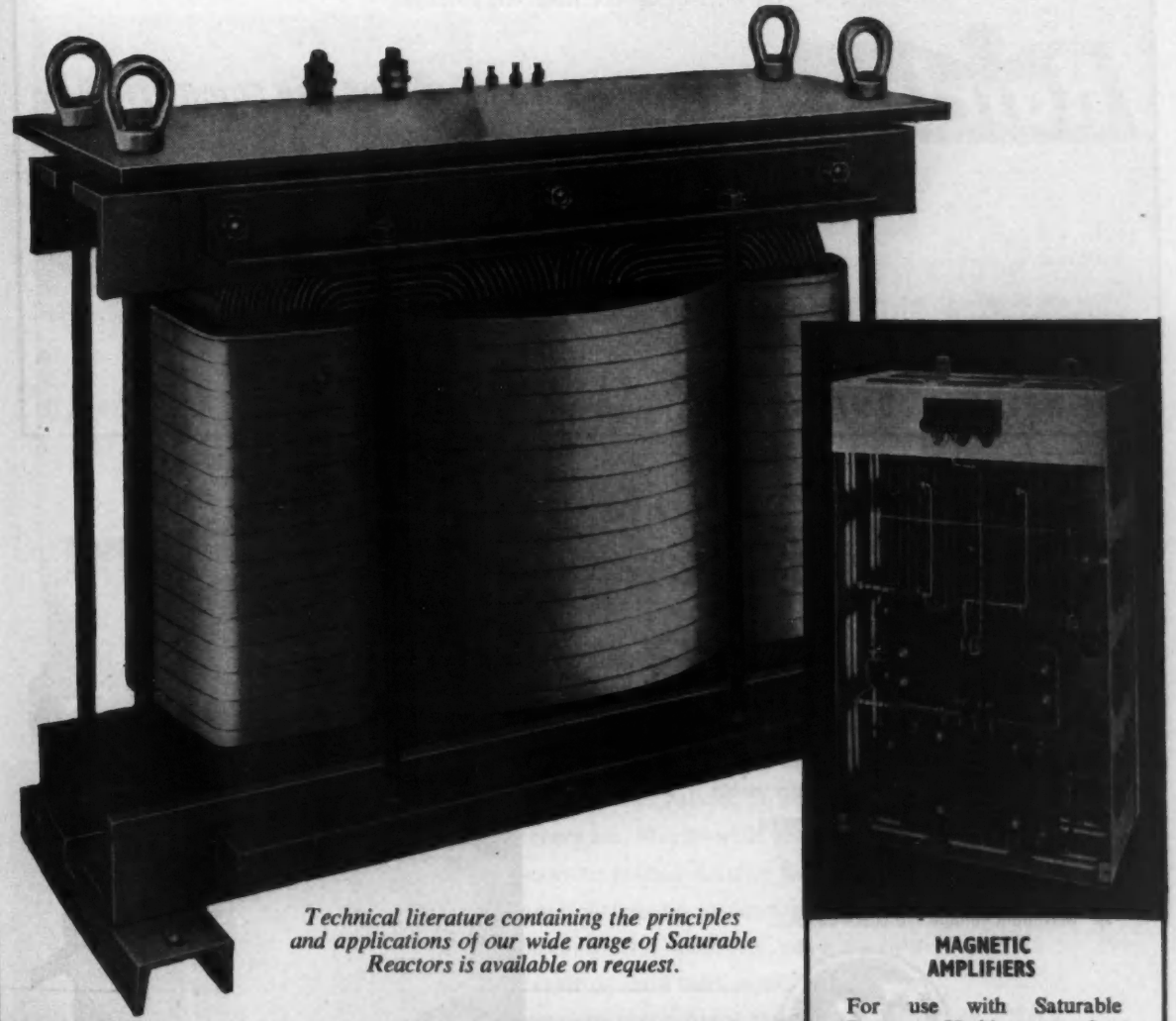
SHARSTON ROAD WYTHENSHAWE MANCHESTER 22

EW.3

HADDON
STANDARD
SATURABLE REACTORS
TRANSDUCERS

Haddon **"STANDARD"** Saturable Reactors—Transductors operate from conventional A.C. line Voltages and provide a choice of D.C. Voltages for Control Windings. Selected from a wide range of individually designed and manufactured **SPECIALS** over past years, the **HADDON STANDARD RANGE** enable the discerning engineer to select **STANDARD EQUIPMENT** for Specific application. 416 standard single-phase designs cover the range 1 kVA to 300 kVA.

They provide the best method of stepless control in both long-term economies and high performance standard.



Technical literature containing the principles and applications of our wide range of Saturable Reactors is available on request.

MAGNETIC AMPLIFIERS

For use with Saturable Reactors Haddon manufacture a standard line of Magnetic Amplifiers.

Operating from 200/250V 50/60 c/s single-phase supply, with input of 0–5 mA DC in 2000/8000 ohms.

Illustrated above is the 1000W Magnetic Amplifier

HADDON

HADDON TRANSFORMERS LIMITED
Victoria Park Industrial Estate, Field End Road, Ruislip, Middx.
Telephone: Byron 9444-8 Telegrams: Hadtrans, Ruislip

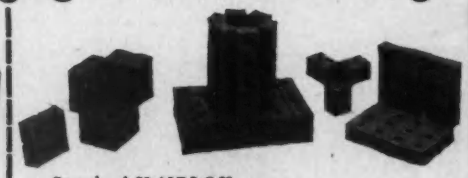
BOOK A V.I.P. PASSAGE FOR YOUR CONSIGNMENT . . .

. . . send it on its way, secure in its special Hairlok tailor-made packaging. Hairlok is the ultimate answer to damage in transit. It is compounded from the finest curled animal hair coated with latex rubber and completely bonded into place to absorb every impact, shock or vibration. The Hairlok Laboratories comprise a team of specialists fully versed in the designing, testing, and constructing of packaging to the most stringent requirements to assure safe transit of the most delicate equipment.

- ATLAS—The HAIRLOK Modulator System for Packaging—provides the answer to standardisation as well as protection.
- HAIRLOK is made in many densities—to absorb a variety of shocks, protect different weights.
- HARLOK Laboratories design complete packages for special items, including individual outers for specific transport/handling problems.

Hairlok -scientific packaging for the scientific age

Vital items of electronic equipment with their own HAIRLOK mouldings and a special self-righting outer case developed by HAIRLOK Laboratories.



Standard HAIRLOK mouldings from the Atlas System range. These can be built up to protect many different shapes and sizes.

For literature and further details, write or phone :

THE HAIRLOK COMPANY LTD., Magna Works, Kathie Road, Bedford. Tel. Bedford 4271

Electrically Operated COUNTER

AT NEW LOW COST

- Rated speed-up to 1000 Counts per minute
- Designed for panel or base mounting
- Centre reset by knob
- Connection by flying leads
- Maximum voltage 110 D.C.—250 A.C.

ENM

English Numbering Machines Limited

Dept. 2K · QUEENSWAY · ENFIELD · MIDDLESEX

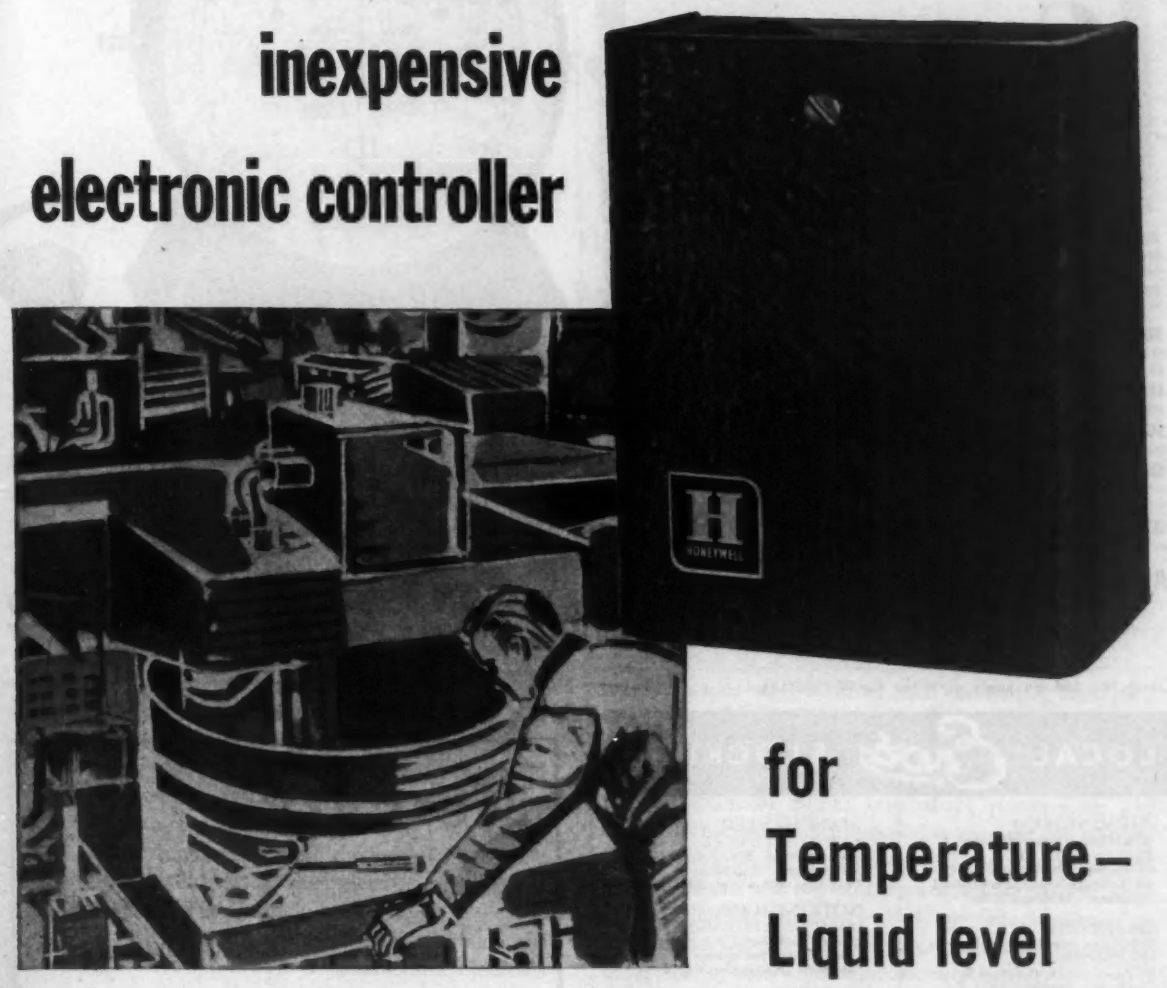
Telephone: HOWard 2611 (5 lines) Telegrams: Numgravco, Enfield

MODEL 442

Full technical information on request

LEADING MANUFACTURERS OF COUNTING AND NUMBERING DEVICES

a compact inexpensive electronic controller



for Temperature–Liquid level

Now, the Versa-Tran — a transistorized controller that's versatile enough to be used in many applications. Small, compact, no valves, no warm up time, gives instant reaction. Works with sensors that can be thermistors or probes. Can be used in such varied applications as packaging machines, injection moulding machines, cooking vats, tyre retreading, and tank level, etc.

Has a temperature control range from —60°F. to +500°F.

The Versa-Tran is the result of traditionally superior Honeywell engineering.

WRITE OR SEND THE COUPON TODAY
Honeywell Controls Limited
Ruislip Road East Greenford
Middlesex WAXlow 2333

I am interested in the Versa-Tran Controller.
Please send me
Specification Sheet
S 1010-6 (Temperature) ☐
S 1017-1 (Liquid Level) ☐

NAME_____

POSITION_____

ADDRESS_____

Sales Offices in the principal towns and cities in the United Kingdom and throughout the world.

Honeywell

First in Control

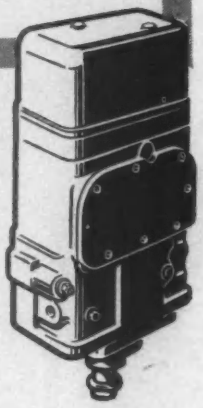
SINCE 1885

Circle No 144 on reply card for further details

Circle **No 145** on reply card for further details

Ardleigh Governors

FOR CLOSE RELIABLE SPEED CONTROL



High quality, top performance governors for all applications demanding accurate control of prime movers. Built to high standards of precision and finish and capable of long, sustained performance with little or no maintenance.

SERIES 300 Suitable for most applications including generator sets, marine propulsion and diesel electric traction.

SERIES 400 Has an extremely high response rate when subjected to very small speed changes.

SERIES 500 Load sensing governors for A.C. generating sets.

SERIES 600 General purpose governors particularly suitable for control of A.C.—D.C. generating sets.

SERIES 700 Developed to fill the need for a small general purpose governor.

ARDLEIGH ENGINEERING LTD

STANDARD IRONWORKS, PORT LANE, COLCHESTER

Telephone: COLCHESTER 3209

Circle **No 146** on reply card for further details

LOCAL Erots STOCKISTS

BIRMINGHAM
BIRMINGHAM TUBE & FITTINGS CO. LTD., (Solderless Tube Fittings only), 48 Holloway Head, Birmingham 1
Telephone : MIDland 3276

BRADFORD
THOMAS WRIGHT (BRADFORD) LTD., 85 Bower Street, Bradford 5
Telephone : Bradford 28831-2

BRISTOL
C. E. KIDD & SON LTD., 15 Rupert Street, Bristol
Telephone : Bristol 27594

COVENTRY
G. E. ADAMS LTD., 401 Broad Lane, Coventry
Telephone : Tile Hill 66472

GLASGOW
J. & T. LAWRIE LTD., Livingstone Street, Clydebank
Telephone : Clydebank 2171

LEEDS
THORITE PNEUMATICS LTD 135/137 West Street, Leeds 1
Telephone : Leeds 35512

LEICESTER
HEADLAND ENGINEERING DEVELOPMENTS LTD., 38 Gartree Street, Leicester
Telephone : Leicester 27782

LONDON
PROCESS PNEUMATICS LTD., 19 Charlton Road, London, S.E.3.
Telephone : Greenwich 6575

MANCHESTER
CAR & CYCLE DEPT., BAXENDALE & CO. LTD., Miller Street, Manchester 4
Telephone : Blackfriars 8282

NOTTINGHAM
DOUGLAS FYFE (ENGINEERS MERCHANTS) LTD., Canal Street, Nottingham
Telephone : Nottingham 51374

RUSHDEN
COX & WRIGHT (SHOE MACHINERY SERVICES) LTD., Wellingborough Road, Rushden
Telephone : Rushden 3139

SALFORD
MODINE PRODUCTIONS LTD., Dawson Street, Greengate, Salford 3
Telephone : DEAnsgate 7011

SHEFFIELD
GEO. TUCKER & CO. (SHEFFIELD) LTD., Shoreham House, Shoreham St., Sheffield 1
Telephone : Sheffield 29691

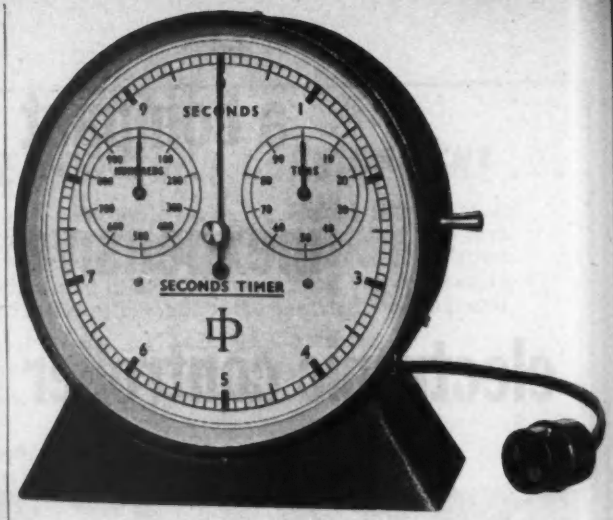
SLOUGH
G. X. ENGINEERS LTD., Gerrards Cross, Slough
Telephone : Gerrards Cross 3954

STOCKPORT
L. L. PRICE (PIPELINES) LTD., Brascop House, 33 Buxton Road, Heaviley, Stockport
Telephone : Stockport 5202

STOKE
COTTON BROS. (LONGTON) LTD., Crown Works, Longton
Telephone : Longton 33021

BENTON & STONE LIMITED, BIRMINGHAM 6.
See Advertisement on page 72

Circle **No 147** on reply card for further details



SECONDS TIMER

SHEWING :
Divisions of One Tenth of a Second.
Visual Record of Tens and Hundreds up to one Thousand.
Instant Start and Stop by Electrical means.
Manual Re-set to Zero.
Special Extra—Reversible Motor for Re-set.

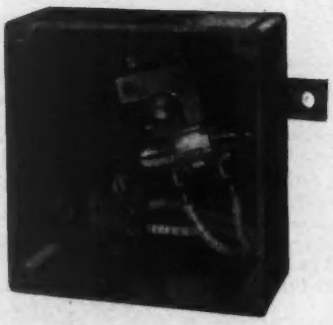
Makers of Timers of all sorts.

DEVON INSTRUMENTS LIMITED
GLOBE HALL WORKS, TOPSHAM. *Topsham 3547*

Circle **No 148** on reply card for further details

Mercury

SWITCHES
SWITCH UNITS
SWITCH RELAYS



Send for illustrated Catalogue

I.A.C. LTD.

Ref. C., 10 CHASE ROAD, LONDON, N.W.10

AWARDS FOR WRITERS

The Electronic Engineering Association and the Radio Industry Council are to award premiums of 25 guineas each for articles, which, in the judges' opinion, are likely to enhance the reputation of the Radio and Electronics Industry and to focus attention throughout the world on British leadership in these fields.

ARTICLES to be judged must EITHER
(a) concern British achievements in radio, television and electronics and have been published, between January and December of any one year, at home or abroad in registered newspapers or journals available to the public, OR
(b) be devoted to electronics and have been published in trade or technical journals serving the steel, food, atomic energy and other industries in which electronic control and production are being increasingly used, OR
(c) tell of British accomplishments in radio, television and electronics and have appeared in a manufacturer's journals circulating overseas; such articles are eligible for one of the six awards.

WRITERS who are salaried wholly or mainly for writing or who are earning 25% or more of their incomes from fees for articles or from royalties are NOT eligible. Joint awards may be made, but BOTH or ALL the writers concerned must be eligible.

CRITERIA will, principally, be :- The value of the article in making known British achievements in radio and electronics; technical merit; originality; presentation and clarity. Importance is also attached to arousing and sustaining interest of lay personnel, such as executives and administrators, and not simply scientists and technicians.

PROCEDURE Authors—or editors—should submit, on publication, a copy of the journal, or relevant pages, proof or reprint, together with a signed declaration that the writer/s is/are eligible, to the Secretary, The Electronic Engineering Association, 11, Green Street, Mayfair, London, W.1, with a request that the article be considered. All entries for this current year should reach the E.E.A. offices before the end of 1960 and not later than 15th January, 1961.

PANEL OF JUDGES

Prof. H. E. M. Barlow, *NSC (Eng), PhD, MIMech E, MIEE, Prof. Electrical Engineering, University College, London.*

B. C. Brookes, *MA, Senior Lecturer, Dept. of Engineering, University College, London.*

A. H. Cooper, *BSc* **F. Jeffery** **G. Reeves**

Dr. R. C. G. Williams, *PhD, BSc (Eng), MIEE, MIMech E, ACGI, DIC.*

THE ELECTRONIC ENGINEERING ASSOCIATION
11, GREEN STREET, MAYFAIR, LONDON, W.1

THE RADIO INDUSTRY COUNCIL
59, RUSSELL SQUARE, LONDON, W.C.1

WRITE NOW
for full details of these Awards, and how to compete, to the E.E.A. As a writer, or editor, YOU can help to create an increased awareness of Great Britain's leading part in the development of radio, television and electronics, by entering or supporting this competition.

Circle No 149 on reply card for further details

LONDEX

midget relays

Londex midget relays, made to the highest standards, are designed for incorporation in electronic equipment and business machines or in other types of industrial control mechanisms where space and weight are limited.

COILS available for A.C. or D.C. working. Continuously rated.

CONTACTS make and break or changeover. Maximum, 3 sets of changeover.

Leaflet No. 1231 C available on request

LONDEX LTD.

Anerley Works, London, S.E.20 Sydenham 3111

Circle No 150 on reply card for further details

"WATFORD" TYPE B COUNTER AND BATCH SELECTOR

This is a General Batch Counter for Counting and Sorting into Batches.

It contains four Dekatron Tubes and a Re-settable Electro-Magnetic Counter.

Each tube has a Selector Switch numbered 0–9.

Total Count 9,999,999,999. Counting Rate up to 4000 per second. Batching any number 1–10,000.

Batch rate 5 batches per second. Input Photo-cell, Electrical Contacts to customer's requirements. The instrument is complete with changeover contacts for controlling external circuits.

WE CORDIALLY INVITE YOU TO SEE US AT OUR **STAND No. 50** AT THE E.I.A. EXHIBITION, ROYAL HORTICULTURAL SOCIETY'S NEW HALL, S.W.1

18th–20th OCTOBER, 1960

PRECISION ENGINEERS LTD.

COLONIAL WAY, STATION ESTATE, WATFORD

Telephone: WATFORD 26259

Circle No 151 on reply card for further details

RELAY USERS

"CORREX" TENSION GAUGES

The only instrument solely designed for accurately measuring tension on *Relays*, *Contacts*, *Switchgear*, and electrical apparatus of all kinds. Gauge measures in grammes, and a large range of sizes is produced to cover from 0.3–2,000 grammes.
Swiss made and guaranteed.

Write for illustrations and prices from the Distributors throughout the U.K.

JAMES W. CARR & CO. LTD.

Dept. SALES 7-15 Rosebery Avenue, LONDON, E.C.1
Telephone TERMINUS 8866 (P.B.X.)

Circle No 152 on reply card for further details

PENNY & GILES

MUDEFORD · CHRISTCHURCH · HANTS

TELEPHONE HIGHCLIFFE 2855

D.G.I. AND A.R.B. APPROVED

PRECISION POTENTIOMETERS

GENERAL DATA

RESISTANCE RANGE
100 ohms. to 100 K ohms.

MECHANICAL RANGE
360 degrees or with stops

ELECTRICAL RANGE
355 degrees or greater

TORQUE
0·025 oz. ins. to 0·25 oz. ins. Depending on Type

All items have low inertia, precision ballraces, aluminium alloy cases and are suitable for operation over an ambient temperature range: minus 50°C to plus 150°C. All Potentiometers are fitted with rear connections—either solder pins or captive leads.

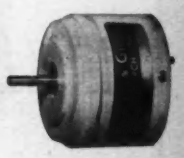
SINGLE AND MULTI-GANGED UNITS.

WRITE FOR DATA SHEETS

STANDARD SYNCHRO MOUNTINGS

SIZE 08

SIZE 11

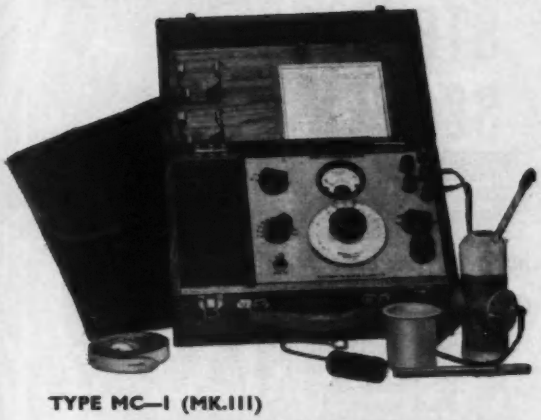


SIZE 15

SIZE 18

Circle No 153 on reply card for further details

Portable . . .



TYPE MC—I (MK.III)

CONDUCTIVITY MEASURING BRIDGE

The type MC-1 conductivity bridge is an invaluable aid to the water engineer in the laboratory or in the field, for the determination of water purity, where it may be depended upon for precise, accurate measurement and trouble free service.

The instrument is supplied complete with an ELECTRONIC SWITCHGEAR patented, non-glass conductivity measuring cell and all accessories, in a convenient hardwood carrying case. The development of low power consumption transistorised circuits, which operate from a small long life dry battery, has resulted in the production of a particularly compact and lightweight precision instrument.

Descriptive leaflet MC-1 available on request.

ELECTRONIC SWITCHGEAR

(LONDON) LTD.

LETCHWORTH · HERTS · TEL: 1853

ELECTROLYTIC CONDUCTIVITY MEASURING SETS, RECORDERS, CONTROLLERS AND CELLS · CONTROLS FOR LIQUID AND SOLID LEVELS · TIMING · PHOTO-ELECTRIC PACKAGING REGISTRATION · ETC.

47 VICTORIA STREET WESTMINSTER, S.W.1 ABBEY 2771/5

Circle No 154 on reply card for further details

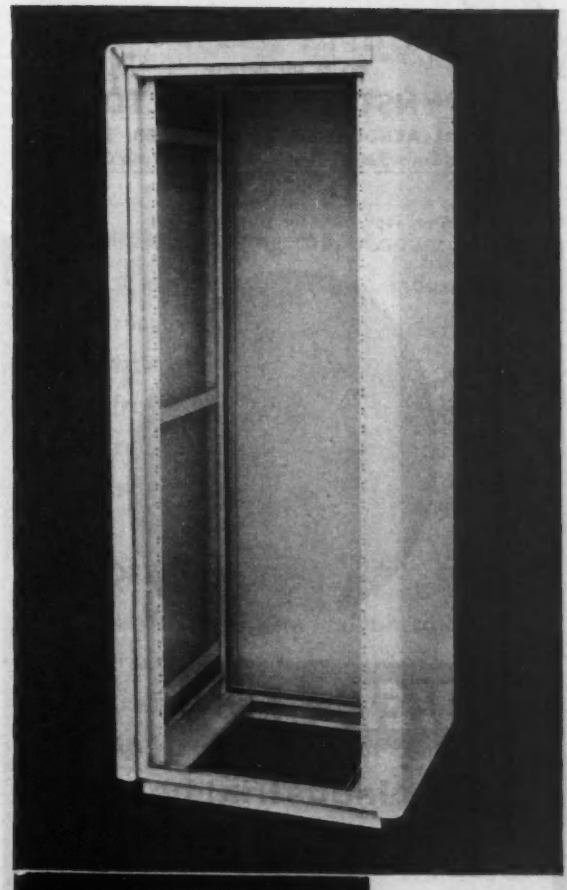
LUNRAC from LUNDS of Wandsworth

The recently introduced standard rack from Lunds of Wandsworth is already making a name for itself. The Lunrac is sturdy, well designed, and easily adaptable to suit varying conditions and specifications.

Note these Lunrac features:

- Rigidly constructed from 10 gauge formed steel sections and finished in silver grey hammered stoving enamel.
- Standard 19" panel mountings tapped O.B.A.
- Easy accessibility through hinged rear door and quick release side panels constructed of 18 G mild steel.
- Price £38 . 10 . 0.
- Facilities for floor mounting or on castors.
- Single or multi-bay assemblies.
- Racks can be dust proofed, force ventilated or sound deadened.

Further details on application to the address below:



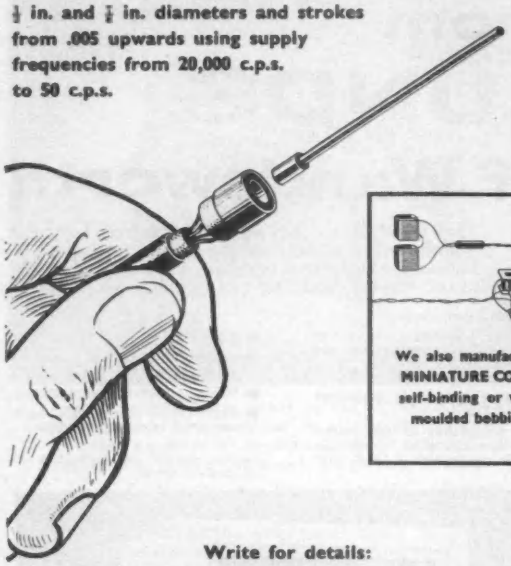
LUNDS OF WANDSWORTH

Bendon Valley, London, S.W.18. Phone : VANdyke 7676

Circle No 155 on reply card for further details

VARIABLE INDUCTANCE LINEAR DISPLACEMENT TRANSDUCERS

Available in ¼ in. *(as illustrated)* **½ in. and ¾ in. diameters and strokes from .005 upwards using supply frequencies from 20,000 c.p.s. to 50 c.p.s.**



We also manufacture MINIATURE COILS self-binding or with moulded bobbins

Write for details:

WYNSTRUMENTS LTD.

STAVERTON AERODROME, GLOUCESTER, ENGLAN

Phone: Churchdown 3264 (3 lines) Grams: "Wynn Gloucester"

Circle No 156 on reply card for further details

FRIEDLAND

Industrial bells

Friedland bells operate by alternating or direct current from 6 to 250 volts.

Please write for the leaflet which gives full specifications of the complete range.

V. & E. FRIEDLAND LTD., Macclesfield, Cheshire.

Circle No 157 on reply card for further details

METAL PHOTO STENCIL SCREEN

DURAMET R M R

DURAMET

allows freedom of design with accurate definition

The DURAMET metal photo stencil screen is an all-metal unit consisting of a metal stencil bonded to metal gauze. It is equally effective for printing on metal, plastic, wood, and paper.

MAIN FEATURES OF DURAMET

- *many times the usual stencil life*
- *consistent fineness of detail*
- *complete freedom and choice of inks and washes*
- *dimensional stability*
- *thick and thin deposits*

RMR

N. M. ROTHSCHILD & SONS

ROYAL MINT REFINERY, 19 ROYAL MINT ST., LONDON, E.1

ROYal 7061

Circle No 158 on reply card for further details

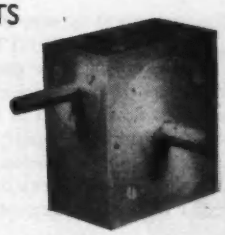
PRECISION GEARS

GEAR HEADS

MECHANISMS

PRECISION INSTRUMENTS

SPURS, HELICALS
MITRE, RATIO BEVELS
SPROCKETS, RACKS
WORMS, WHEELS
REDUCTION BOXES—→



SMALL PRECISION GEARS UP TO ADMIRALTY CLASS I

NORMAL RANGE 24 TO 100 D.P. IN ANY RECOGNISED MATERIAL

WRITE FOR OUR BROADSHEET. CONSULT US FOR THE SOLUTION OF YOUR GEAR PROBLEMS

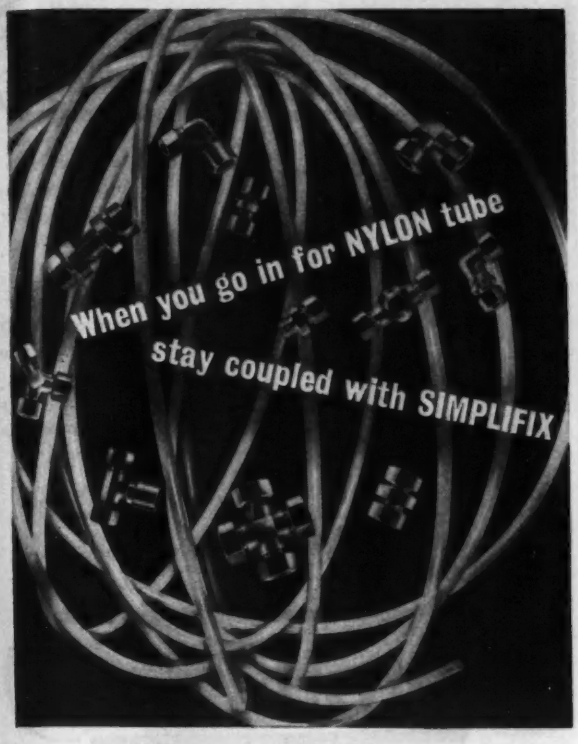
S. H. Muffett, Ltd.

MOUNT EPHRAIM WORKS

ROYAL TUNBRIDGE WELLS KENT

A.I.D. APPROVED **Tel.: 20231-2**

Circle No 159 on reply card for further details



To lightness, ease of handling and flexibility of nylon tubing . . . add ease of coupling . . . with SIMPLIFIX NYLON-TUBE COMPRESSION FITTINGS. No work is required on tube end . . . ingenious brass olive makes perfect seal and prevents tube from twisting when joint is made.
Simplifix couplings are economical too. Standard bodies are used for nylon tube—with special olives and securing nuts.
So if you use both copper and nylon tube, costs and stocks can be kept to the minimum.
There is an enormous range of Simplifix couplings to choose from—
over 12,000 different types and sizes!

Simplifix compression couplings for nylon tube.
Simplifix olives and securing nuts for nylon tube are available for standard coupling bodies in O.D. tube sizes of $\frac{3}{16}$", $\frac{1}{4}$", $\frac{5}{16}$", $\frac{3}{8}$" and $\frac{1}{2}$". Complete couplings for nylon tube are also available in same range of sizes.
Nylon tube can also be supplied by Simplifix in a wide range of colours and sizes.

Technical literature sent on request.
Technical representatives available on call.

SIMPLIFIX

SIMPLIFIX COUPLINGS LIMITED · HARGRAVE ROAD
MAIDENHEAD · BERKS · TEL: MAIDENHEAD 5100

A member of the ALENCO Group of Companies

Circle No 160 on reply card for further details

Problems?

could Screen Printing solve them?

As Europe's leading supply house we offer a complete service to industry. Our range of hand, semi- and fully automatic machines can handle anything from transistors to 20 ft. banners. Our technicians will be pleased to discuss your problems.

IMPORTANT

We publish a regular bulletin to our industrial customers, giving details of the latest developments in Screen Printing. If you use, or are contemplating using, Screen Printing please make certain that you are on our mailing list.

SCREEN PROCESS SUPPLIES LIMITED

WALHAM HOUSE · WALHAM GROVE · LONDON SW6 FULham 9555

Circle No 161 on reply card for further details

Simplified Control with
NEUMO
AIR OPERATED PUMPS
and MOTORS

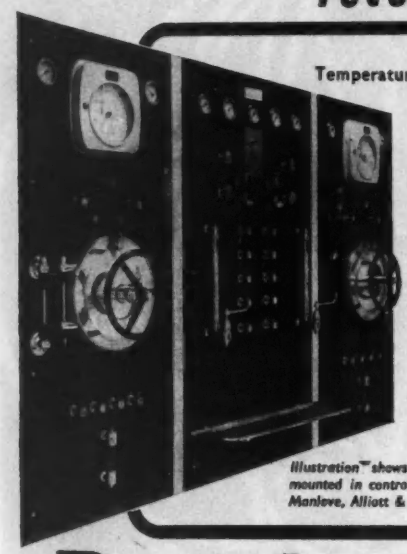
Many industrial users are finding that control of liquid flow by means of a simple valve in the delivery line is all that is required when using Neumo positive displacement air operated pumps. This valve may be at any distance from the pump enabling operators to control pumps at distant points of delivery.
The system is reliable because no extra control gear is employed, the pump merely stalling by back pressure in the delivery line and recommencing delivery upon release of the pressure. The possibility of raising undue pressure in the line is avoided by automatic over-load devices in the pump which can be set to come into action at a predetermined pressure.
Pumps are made in a wide variety of materials to cope with all liquids. Neumo motors containing only two moving parts are a safe, reliable means of obtaining reciprocating motion and again may be stalled without damage.

Write for further details to:

NEUMO LIMITED
South Coast Road, PEACEHAVEN, Sussex.
Telephone: Peacehaven 2115 & 3354.

Circle No 162 on reply card for further details

TEMPERATURE *recording*



Temperature Recorders with single or dual pen for flush panel or wall mounting.

Mercury-in-steel actuation. Also Dial Thermometers for all process work. Bi-metal, mercury-in-steel or vapour pressure.

Illustration shows Rototherm instruments mounted in control panel built by Messrs. Manlove, Alliott & Co., Ltd., of Nottingham

Rototherm

THE BRITISH ROTOTHERM CO. LTD.
Merton Abbey, London, S.W.19. Phone: LIBerty 7661
Nottingham Factory: Hollis St., New Basford. - Phone: 77847

MUCH CLOSER VOLTAGE ±½% CONTROL

with
Carbon Pile Wattages and
Transistorised Sensitivity

REMEMBER POPPY DAY

Regulation closer than ± ½% between extremes of temperature from —60°c to +70°c. Speed of response 50/60 milliseconds.
Dimensions 5" x 6" x 5½" high Weight 4 lb.

Model shown is for the control of a 28 volt D.C. generator for use on aircraft.

NEWTON DERBY

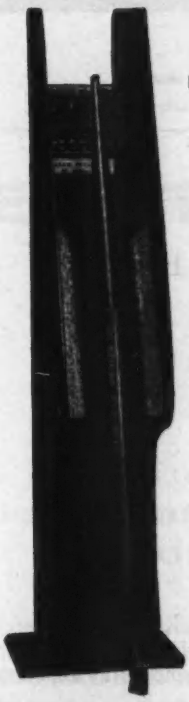
NEWTON BROS. (DERBY) LIMITED
ALFRETON ROAD DERBY
Telephone: Derby 47676 (4 lines) *Grams: DYNAMO, DERBY*
London Office: *IMPERIAL BUILDINGS, 56 KINGSWAY W.C.2.*

Circle No 164 on reply card for further details

THE ELECTRONIC INDUSTRIES SOLDERING TOOL FOR THE TRANSISTOR AGE etc.

ADCOLA

(Regd. Trade Mark)



¼ BIT MODEL (Cat. No. 70)

PROTECTIVE SHIELD (Cat. No. 68)

ELECTRIC SOLDERING EQUIPMENT

Manufactured in all Volt Ranges from 6/7 to 230/50 Volt with elements Insulated from Earth

A PRODUCT FOR PRODUCTION

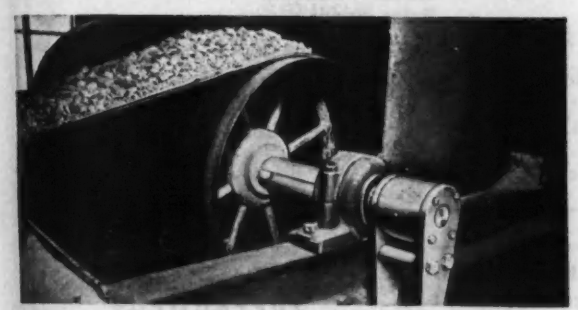
Designed for continual use on bench line assembly

BRIT. FOREIGN PATS. AND REG. DESIGNS ETC. Standards approved in all leading countries

Catalogues
Head Office, Sales & Service
ADCOLA Products Ltd
GAUDEN ROAD
CLAPHAM HIGH STREET
LONDON SW4
Telephones
MACaulay 3101 & 4272

Circle No 165 on reply card for further details

RENOLD Sprag Clutches



for *BACKSTOPPING

as illustrated on this conveyer headstock drive

***A shaft in conjunction with one race can rotate freely in one direction but is prevented from reversing; there is no measurable reverse backlash**

Write for catalogue giving details of our comprehensive range of over 70 standard sizes for backstopping, indexing and silent overrunning with low drag.

RENOLD CHAINS LIMITED
SPRAG CLUTCH UNIT
50, CATHEDRAL ROAD
CARDIFF

Circle No 166 on reply card for further details

Otter

REGD

WORLD PATENTS INCLUDING PATENT NUMBERS 600051, 622781, 624905, 657434, 713443, 749716, 774911, 782668 AND OTHERS. ALSO OTHER PATENTS PENDING

SNAP ACTION

THERMOSTATS & SAFETY CUT OUTS

For Quartz Crystal control, Radar & Electronic Equipment Control Gear and Airborne Equipment

- ★ **Individually and accurately factory set**
- ★ **Long life and stability**
- ★ **Robust and reliable**
- ★ **Up to 20 amp. 250 V. rating**
- ★ **TROPICALISATION—metal parts may be silver plated, and top grade insulation is used.**

All Otter thermostats "Press their contacts together to open them with a SNAP!"

OTTER CONTROLS LIMITED
OTTERS' OLE, BUXTON, DERBYSHIRE
Phone Buxton 650 (2 lines)

O/2

CLASSIFIED ADVERTISEMENTS

DISPLAY ANNOUNCEMENT RATES:—	1 insertion 40/- per single col. inch 6 insertions 38/- per single col. inch 12 insertions 36/- per single col. inch
LINEAGE ANNOUNCEMENT RATES:—	4/- per line. 5% discount 6 insertions, 10% discount 12 insertions
BOX Nos.:—	1/- extra will be charged
COPY DATE:—	Advertisements for November issue to be received not later than October 24th.

SITUATIONS VACANT

AUTOMATIC CONTROL ENGINEERS

Ferranti

WYTHENSHAWE
Manchester

The Company is engaged in important development work on advanced systems of automatic control for:

Industrial and chemical processes
Power generation
Guided missiles

There are a limited number of vacancies and applications are invited from physicists and engineers who would like this opportunity of joining the team. Current projects include digital automatic control systems for chemical and boiler plants (the first in this country) and advanced forms of the Bloodhound Guided missile system.

Preference would be given to applicants having experience in one or more of the following fields:

Analogue or digital computer techniques
Digital data handling
Electro-mechanical devices
Servo systems
Radar techniques
Pulse circuit design
Process control instruments

Minimum qualifications H.N.C. or degree in physics, electrical or mechanical engineering.
Salaries in the range £750 to £2,000 p.a. according to qualifications and experience.
Forms of application can be obtained from T. J. Lunt, Staff Manager, Ferranti Limited, Hollinwood, Lancs.

Please quote reference DB.

AREA SALES ENGINEER

required by

CONTROLS DIVISION

AUDLEY ENGINEERING CO., LTD

GLOUCESTER

This is a senior appointment which has been created due to expansion. The successful applicant will be responsible for promotion of the interests of the Division in the broad field of automatic control and industrial instrumentation in the North of England.

Applicants should have had considerable experience of automatic control systems and instrumentation. A.M.I.Mech.E. or A.M.I.E.E. would be an advantage and a broad background of Sales experience would also be an asset.

Top salary and conditions of service are offered together with excellent prospects. Superannuation scheme in operation and Company car provided.

Please write brief details of age, experience and qualifications to:

MR. D. G. d'A. RUSSELL,
PERSONNEL AND TRAINING MANAGER
AUDLEY ENGINEERING CO., LTD
NEWPORT, SHROPSHIRE.

Vacancy occurs for **TECHNICAL SALES ENGINEER.** Knowledge of control circuits and control techniques essential. Housing available. Apply stating salary required to Electrical Remote Control Co. Ltd., Harlow, Essex.

Telephone your classified advertisement to MUSEUM 8252

TESTER REQUIRED with experience in timers, relays and control panels. 5-day week. Housing available. Apply to Electrical Remote Control Co. Ltd., Harlow, Essex.

INSTRUMENT ENGINEERS

Engineers experienced in process control and instrumentation are invited to apply for a progressive post which has become available owing to our programme of expansion. Interesting work with wide prospects. Salary according to experience.

Apply Box No. CI33

Own Staff informed

CONTROL AND ELECTRICAL ENGINEERING

We are working on the design and development of an increasing range of industrial control equipment covering the following projects:

ENGINE CONTROL SYSTEMS
FLIGHT CONTROL SYSTEMS
TEMPERATURE CONTROL
SYSTEMS ENGINEERING
SERVO MECHANISMS
FLOWMETERS
STATIC INVERTERS

To LEAD sections carrying out basic circuit and development work on these systems we invite applications from

SENIOR ELECTRICAL ENGINEERS

who have had experience on magnetic amplifiers, transistor circuits, pulse techniques or servo mechanisms and have a degree in electrical engineering or physics, or H.N.C. (Electrical).

To carry out theoretical studies and follow up with practical work on the design of semiconductor static inverters, we invite applications from

SENIOR ELECTRONIC ENGINEERS

with a sound knowledge of the mathematical treatment of servo mechanism theory and design. Additional experience of magnetic amplifiers, transformers, transistor and S.C.R. circuit design will be a useful asset

VACANCIES ALSO EXIST FOR
ELECTRICAL AND ELECTRONIC ENGINEERS
with slightly less qualifications where advancement will depend solely upon ability.

Full particulars, in confidence, should be addressed to:
THE PERSONNEL MANAGER (REF 685)
THE DE HAVILLAND AIRCRAFT CO. LTD
HATFIELD · HERTS

ULTRA

CONTROLS AND INSTRUMENTATION

ENGINEERS

A number of senior staff appointments are now available in the research and development laboratories of the engineering department at

Western Avenue, Acton, W.3.

The positions offered cover:—

(a) the engineering research and assessments of control and instrumentation systems and components.

(b) the development of complete systems and components as applicable to a wide range of control projects including gas turbines, airborne instrumentation, nuclear reactors, magnetic and semi-conductor amplifiers.

Candidates for these positions in a progressive and expanding company, already one of the foremost in the engine control field, should have adequate academic qualifications and related experience in one of more of the branches mentioned. They may expect salaries which encourage creative work in responsible positions.

The Company offers a full range of employment benefit, including a Pensions/Life Assurance Scheme.

Please write, in confidence, giving personal details and stating present salary level, to

The Personnel Officer,
Ultra Electronics Ltd.,
Western Avenue, Acton, W.3.

FOXBORO-YOXALL LTD.,
REDHILL, SURREY

TECHNICAL ASSISTANTS

Young men possessing a general engineering background, preferably in process plant operation or instrumentation, coupled with an educational standard of the O.N.C. in Mechanical or Electrical engineering, seeking an opportunity to utilise this knowledge in the instrument engineering field, are requested to apply, in writing, giving details of their education and experience.

JUNIOR LECTURER

A position is now vacant in a modern, well equipped laboratory and lecture room for a young graduate to assist in the training of instrument engineers and mechanics.

Initially, the desire to mix with people and the ability to pass on technical information in a lucid manner are more important than an understanding of process control problems, as the successful candidate will receive full training.

This is an interesting position, eventually offering the opportunity to contribute to research and development work in addition to lecturing duties.

Applications for the above appointments, giving complete details of career and educational background, should be addressed to the Staff Manager.

KUWAIT OIL COMPANY LTD.

requires an

INSTRUMENT ENGINEER

for service in

KUWAIT

Applicants should hold a University Degree in Electrical Engineering or Associate Membership of the I.E.E.; they should have at least 5 years, experience in industry, after qualifying, in design and application, and should be in the age range 27—40.

The work will primarily entail responsibility for the design and installation of electrical and electronic control of process plant and transmission systems, installation and maintenance of industrial television equipment, and control of instrument calibration and maintenance workshop. It will also include some administrative responsibility with regard to contract work and to stores.

Local salary will be dependent on qualifications and experience but will be not less than £2600 p.a. Kit allowance of £85 is payable. There is no tax on personal income in Kuwait.

Write for application form giving brief details and quoting K.2745 to Box D/25, c/o Hanway House, Clarke's Place, E.C.2.

BUSINESS OFFERS

Bristol Office—Firm of Industrial Electronic Engineers contemplating branch office would welcome hearing from Bristol Company or Technical Branch Office in a complementary field, with a view to a working arrangement.

Box No. C134, c/o *Control.*

SUPPLIES & SERVICES SECTION

CAPACITY AVAILABLE

BUSINESS OPPORTUNITIES

CONSULTANTS

SPECIAL SERVICES

PRESSINGS IN ALL METALS
up to 60 tons

Press tools manufactured in our own toolroom. Light assemblies—Domestic, Electrical and Mechanical. All finishes. A.I.D. and A.R.B. approved. Advice and estimates given free.

Inquiries to:
METAL COMPONENTS LTD.
DOLPHIN ROAD
SHOREHAM-BY-SEA
SUSSEX
Telephone:
Shoreham-by-Sea 2224–5

TECHNICAL TRANSLATIONS by a team of graduate experts, covering many technical fields and languages. P. Suchodolski, F.I.L.(Eng.), 70 Greenfield Gardens, London, N.W.2. Telephone: MEAdway 2239.

GEARS

50,000 PRECISION INSTRUMENT GEARS OF ALL TYPES FROM STOCK!
(Now including Spiral Bevels)
Write for fully comprehensive Catalogue
THE DAVALL GEAR COMPANY LIMITED
POTTERS BAR, MIDDLESEX
Telephone Number: Potters Bar 2382

ELECTRICAL CONNECTORS

PLUGS AND SOCKETS

more than 1,000,000 in stock, covering over 50 different ranges, British and American.

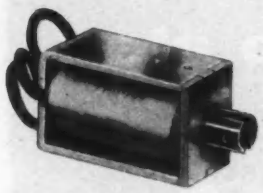
Stock list on application to:

SASCO,

Nutfield, Redhill, Surrey

Telephone: Redhill 5050

SOLENOIDS



PHIL-TROL SOLENOIDS

New 6 Page Leaflet (No. 108) now available. Covers small and medium solid core types including new types 45, 35, 36 and 37.

Send for your copy now.

Quick Delivery Solenoids are normally despatched same day as receipt of order

PHILLIPS CONTROL (G.B.) LTD. Dept. E, Farnborough, HANTS. phone: Farnborough 1120

SPECIAL EQUIPMENT

TELEPRINTERS
PERFORATORS
REPERFORATORS
TAPE READERS

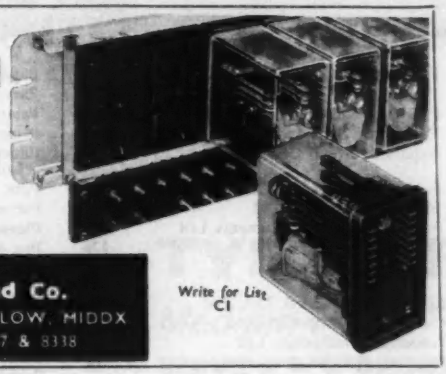
Terminals and V.F. Telegraph multi-channel units; Testing Equipment, Test Frames, Telephone Carriers and Repeaters; Signalling Rectifiers and Relays, Transformers, Transmit and Receive Filters; Repeating and Retardation Coils; Racks, Relay Bases, Uniselectors, Remote Control Transmitters, British, American, and German Equipment.

BATEY & CO., GAIETY WORKS, Akeman Street, Tring, Herts.
Tel.: TRING 2183 and 2310

RELAY SYSTEMS

The Plug-in Relay System

The most highly developed Relay System available



Sole Distributors
D. ROBINSON and Co.
717 LONDON ROAD, HOUNSLOW, MIDDX
Tel.: HOUnslow 6266, 6267 & 8338

Write for List C1

AGENCIES WANTED

PROGRESSIVE COMPANY of instrument makers and precision engineers are willing to enter into licensed agreement with patentees of electronic and mechanical instruments with good market prospects.

Adequate facilities for development and production.

Inquiries to :

V. Lovett, Esq.
H. & B. PRECISION ENGINEERS
Station Estate, Watford, Herts.

1st

ELECTROMECHANICS
HYDRAULICS
PNEUMATICS
INSTRUMENTS
DATA PROCESSING
SYSTEMS & APPLICATIONS
WHO'S WHO
BUYERS' GUIDE

EARLY OCTOBER

CONTROL's first INDUSTRY GUIDE AND DIGEST will be published. As well as summarizing the year's new and important control systems, components and instrumentation, it will include a revised and enlarged Buyers' Guide, and the first-ever specialized Who's Who in the field of control engineering.

FOR ADVERTISING RATES AND SUBSCRIPTION DETAILS WRITE OR PHONE
ROWSE MUIR PUBLICATIONS LIMITED
THE ROWSE MUIR BUILDING, 77-79 CHARLOTTE ST. LONDON W.1 MUSEUM 8252

Circle **No 167** on reply card for further details

SINCE 1880

Makers of Precision Gears. All types up to 8" diameter 10 to 64 D. P.

Send your enquiries to OUR NEW FACTORY

G. W. EVERY & SONS LTD.

FIRST AVENUE, DENBIGH ROAD, BLETCHLEY, BUCKS

Telephone: Bletchley 2476

ADVERTISERS IN THIS ISSUE

Adcola Products Ltd 197
A.D.S. Relays Ltd 172
Advance Components Ltd 179
A.E.I. Ltd (Electronic Apparatus Div.) 31
A.E.I. Ltd (Instrumentation Div.) 19
A.E.I. Ltd (Radio and Electronic Components Div.) 139
A.E.I. Ltd (Telecommunications Div.) 155
Aircraft Marine Products Ltd 13
Airmec Ltd 169
Alexander Controls Ltd 41
Ampex Great Britain Ltd 135, 137
Amphenol (Great Britain) Ltd 180
Anglo-American Vulcanized Fibre Co. Ltd 48
Ardleigh Engineering Ltd 190
Armstrong Whitworth Aircraft Ltd, Sir W. G. 17
Associated Transistors Ltd 82

Bailey & Co. Ltd, Sir W. H. 184
Baldwin Instrument Co. Ltd 39
Baldwin Instrument Co. Ltd (Fluid Power Div.) 65
B & R Relays Ltd 167
Benton & Stone Ltd 72, 190
Birfield Industries Ltd 160
Blakeborough and Sons Ltd, J. 66
British Arca Regulators Ltd 137
British Electrical Development Association 23
British Electric Resistance Co. Ltd, The 170
British Ermeto Corp. Ltd 55
British Rototherm Co. Ltd, The 196
Bristol Siddeley Engines Ltd 49
Brookhurst Igranic Ltd 16
Bulmers (Calculators) Ltd 46
Burgess Products Co. Ltd 60

Cambridge Instruments Co. Ltd 168
Carr and Co. Ltd, James W. 192
Carter Gears Ltd 52
Cockburns Ltd 56
Continental Connectors Ltd 51
Counting Instruments Ltd 143
Crosby Valve & Eng Co. Ltd 157

Davy & United Instruments Ltd 162
Dewhurst and Partner Ltd 175
Devon Instruments Ltd 190

Ekco Electronics Ltd 149
Electronic Engineering Association, The 191
Electronic Switchgear (London) Ltd 193
Elliott Brothers (London) Ltd (Servo Components Div.) 9
Engel and Gibbs Ltd 75
English Electric Co. Ltd, The 59, 185
English Numbering Machines Ltd 188
Epsylon Industries Ltd 34
Ericsson Telephones Ltd 73
Ericsson Telephones Ltd (Instrument Div.) 1

Ether Ltd 26, 27, 183
Evans Electroselenium Ltd 57
Evershed and Vignoles Ltd 10, 11
Every and Sons Ltd, G. W. 202
Expanded Metal Co. Ltd, The 76

Ferranti Ltd 45
Fielden Electronics Ltd 15, 69
Firth Cleveland Instruments Ltd 24
Fortiphone Ltd 176
Friedland Ltd, V. & E. 194

General Electric Co. Ltd, The 50
Gesterlith Distributors Ltd 43
Goodmans Industries Ltd 29
Gordon and Gotch (Sellotape) Ltd 12
Graviner 178
G.W.B. Furnaces Ltd 40

Haddon Transformers Ltd 187
H. & B. Precision Engineers Ltd 192
Hairlock Co. Ltd, The 188
Hendrey Relays Ltd 180
HML Engineering Ltd 181
Honeywell Controls Ltd 189

I.A.C. Ltd 190
Imhof Ltd, Alfred 165
Insuloid Manufacturing Co. Ltd 182
Integra Leeds & Northrup Ltd 161
International Computers & Tabulators Ltd 61

Jones Tate and Co. Ltd 21

K.D.G. Instruments Ltd 172
Ketay Ltd 148
Klaxon Ltd 176

Lancashire Dynamo Electronic Products Ltd 2, 153
Lewis Spring Co. Ltd, The 178
Lock and Co. Ltd, A. M. 186
Lockheed Precision Products Ltd 71
Londex Ltd 192
Lunds of Wandsworth 193
Lyons Ltd, Claude 174

Maxam Power Ltd 86
Midland Silicones Ltd 47
Morganite Resistors Ltd 58
Muffett Ltd, S. H. 194
Murphy Radio Ltd 74

Negretti & Zambra Ltd 141
Neumo Ltd 196
New Electronic Products Ltd 158, 159
Newton Brothers (Derby) Ltd 196

Oliver Pell Control Ltd 64
Otter Controls Ltd 197

Painton and Co. Ltd 63
Panellit Ltd 171
Parvalux Ltd 168
Pelaphone Ltd 62
Penny & Giles 192
Phoenix Telephone and Electric Works Ltd, The 163
Pilot Plug Gauge Co. Ltd, The 4
Plessey Co Ltd, The 18
Plessey Co. Ltd, The (Semimetals Div.) 203
Pye & Co. Ltd, W. G. 166
Pyrotenax Ltd 80

Radiovisor Parent Ltd 154
Rank Cintel Ltd 67
Reliance Manufacturing Co. (Southwark) Ltd 173
Renold Chains Ltd 197
Research and Control Instruments Ltd 147
Rocol Ltd 22
Rothschild & Sons, N. M. 194
Rotork Eng Co. Ltd 152

Schrader's Son, A. 81
Screen Process Supplies Ltd 195
Semiconductors Ltd 204
Servomex Ltd 70
Simmonds Ltd, L. E. 170
Simplifix Couplings Ltd 195
Sperry Gyroscope Co. Ltd, 145
Square D Ltd 7
Standard Telephones & Cables Ltd 28, 68
Standard Telephones & Cables Ltd (Instrumentation and Control Div.) 151
Stone and Co. (Deptford) Ltd, J. 182
Stone-Chance Ltd 54
Southern Instruments Ltd 150
Superflexit Ltd 30

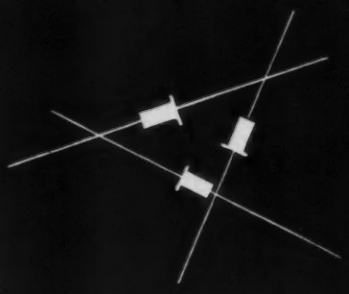
T.A.L. Numatics Ltd 6
Telehoist Ltd 53
Telephone Manufacturing Co. Ltd 44
Telequipment Ltd 164
Texas Instruments Ltd 85
Thompson Instrument Co. Ltd, John 14
Thompson Ltd, J. Langham 32
Thorn Electrical Industries Ltd 25, 177
Tinsley and Co. Ltd, H. 174
Trist & Co. Ltd, Ronald 14

Ultra Electronics Ltd 33
Unbrako Socket Screw Co. Ltd 8

Varilectric Ltd 20
Venner Electronics Ltd 42
Vickers Armstrongs (Engineers) Ltd 5

Westool Ltd 77
Wilcox & Co. Ltd, Edward 186
Williams and James (Engineers) Ltd 184
Winston Electronics Ltd 156
Wynstruments Ltd 194

hats off to SIMET SILICON RECTIFIERS



First again!

Complete range of **TYPE APPROVED**

Medium Power Top Hat

RECTIFIERS

from

100 P.I.V. to **800** P.I.V.

0·75 AMP AT 25°C — 0·5 AMP AT 100°C

SIMET

"G" Series Rectifiers, which is the range from which these Type Approved devices have been developed, offer high temperature operation —250mA, at 150°C up to 600 P.I.V. —and high voltage operation up to 1000 P.I.V. —**and are available from stock**

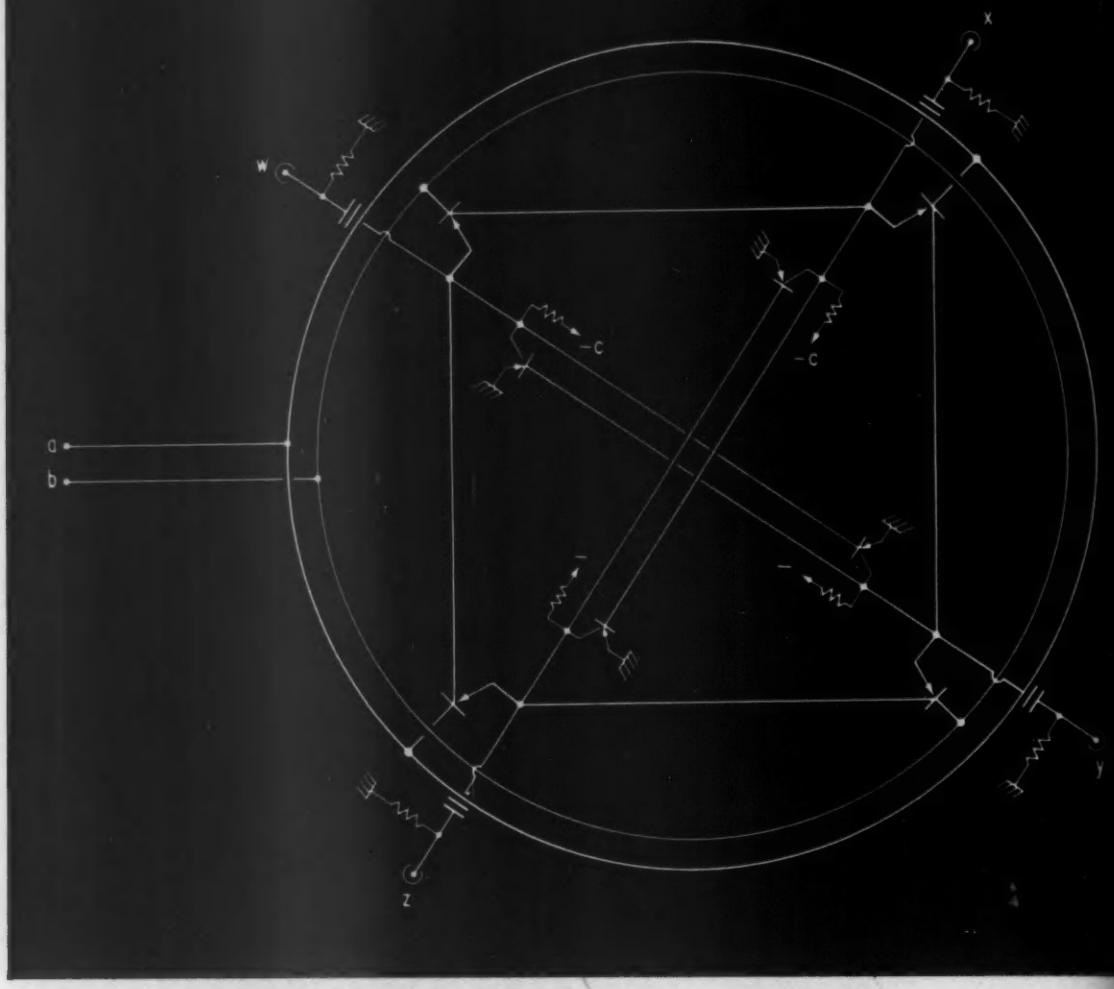
E.V. SPECIFICATION	P.I.V.	COMMERCIAL EQUIVALENTS
CV 7030	800v	8G7
CV 7029	600v	6G8
CV 7028	400v	4G8
CV 7027	200v	2G8
CV 7026	100v	1G8

Plessey

COMPONENTS GROUP

Semimetals Division
The Plessey Company Limited
Woodburcote Way Towcester Northants
Telephone: Towcester 312
Overseas Sales Organisation
Plessey International Limited Ilford Essex
Telephone: Ilford 3040

Circle **No 199** on reply card for further details



YOU KNOW WHICH IS BETTER!

Just by looking at these two circuits, the experienced designer knows which is better. He knows that the simple, straightforward circuit shown above, incorporating Semiconductors' SB Transistors, offers real performance-improving, cost-saving advantages.

- **If you want circuit simplification**
- **If you want high volumetric efficiency**
- **If you want fewer joints**
- **If you want parameter variation immunity . . .**

. . . it will pay you to investigate the benefits of Semiconductors' transistors for Directly Coupled Circuits.

Write or 'phone Semiconductors' Applications Laboratory — Swindon 6421.

Semiconductors Limited
CHENEY MANOR · SWINDON · WILTSHIRE
Telephone: Swindon 6421

ONE OF THE Plessey GROUP OF COMPANIES

Circle No 200 on reply card for further details

XU

XU